PERFORMANCE OF *TRICHOGRAMMA EVANESCENS* FOR ECO-FRIENDLY MANAGEMENT OF LEPIDOPTEROUS INSECT PESTS OF CABBAGE

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CERTIFICATE

This is to certify that thesis entitled, "PERFORMANCE OF TRICHOGRAMMA EVANESCENS FOR ECO-FRIENDLY MANAGEMENT OF LEPIDOPTEROUS INSECT PESTS OF CABBAGE" submitted to the Faculty of ***Agriculture****, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (MS) IN ENTOMOLOGY, embodies the result of a piece of bona fide research work carried out by SANJIB KUMAR GOSWAMY,* ***Registration no. 10-04229*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Date: December, 2012
Place: Dhaka, Bangladesh

(Prof. Dr. Md. Razzab Ali)
Supervisor

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ABSTRACT

A field experiment was conducted in the experimental farm of Sher-e-Bangla Agricultural University, Bangladesh during the period from October 2011 to March 2012 to evaluate the performance of *Trichogramma evanescens* for eco-friendly management of Lepidopterous insect pests of cabbage. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications and nine treatments viz. T_1 (Tricho Paper Card @ 0.20 g/plot at 5 days interval), T_2 (Tricho Paper Card @ 0.30 g/plot at 5 days interval), T_3 (Tricho Paper Card @ 0.40 g/plot at 5 days interval), T_4 (Tricho Paper Card @ 0.50 g/plot at 5 days interval), T_5 (Tricho Paper Card @ 0.20 g/plot at 10 days interval), T_6 (Tricho Paper Card @ 0.30 g/plot at10 days interval), T_7 (Tricho Paper Card @ 0.40 g/plot at 10 days interval), T_8 (Tricho Paper Card @ 0.50 g/plot at10 days interval) and T_9 (untreated Control). It was observed that T_4 treatment performed best in managing lepidopterous insect pests of cabbage based on the lowest % leaf infestation (27.70), lowest number of holes /leaf of a plant (3.30), lowest number of larva (3.50), lowest (%) leaf area damage (1.20), lowest % head infestation by number (10.50) and highest % infestation reduction over control on all parameters at vegetative stage of plant. Again, the lowest leaf infestation intensity (7.40%), lowest number of holes / infested head (13.00), lowest number of larva / infested head (1.30), lowest % infestation of head by number (3.30), lowest % head infestation by weight (1.70) were achieved at harvesting stage from the same treatment (T_4) whereas the highest values of all these parameters was achieved from untreated Control treatment (T_9) . The yield contributing characters provided best performance in yield which found in T_4 where yield was increased (105 %) over control giving maximum yield 93.70 ton/ha. Form the study it was found that there is a strong negative relationship between leaf infestation intensity and single head weight and between leaf infestation intensity and yield (t/ha). It also observed that there is a strong positive relationship between number of larvae and leaf infestation intensity, between number of larvae and leaf area damage of cabbage and between number of larvae/infested head and numbers of holes/infested head.

ACCRONYMS

ABBREVIATION	FULL NAME
AEZ	Agro-Ecological Zone
et al.	and others
BBS	Bangladesh Bureau of Statistics
Tricho.	Trichogramma
°C	Degree celsius
DAT	Days after Transplanting
etc	Etcetera
FAO	Food and Agriculture Organization
ha	Hectare
kg	Kilogram
m	Meter
no.	Number
%	Percent
RCBD	Randomized Complete Block Design
m^2	Square meter
t	ton

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CHAPTER I

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata* L.) locally known as ‘Bhadha Kopi’ or ‘Pata Kopi’ is a popular and the most common winter vegetable crop grown from seed in Bangladesh. It is one of the five leading vegetables in the country which belong to the Cruciferae family. Cabbage is a leafy vegetable rich in vitamin C, vitamin E and tryptophan; an important amino acid for our body (Rashid, 1993). The consumption rate of vegetables in our country is 30 kg/head/yr but in developed countries it is 7-8 times higher (FAO, 2004). FAO (2004) claimed that at least 5% of total calories should have come from vegetables and fruits, which may fulfill the requirement of vitamins and minerals of the body. In 2010-2011, 207 thousand metric tons (BBS 2011) of cabbage was produced, which ranked fifth among the vegetables produced in Bangladesh. The yield produced by cabbage in Bangladesh is 75-100 ton/ha depending on selection of variety and season (Rashid *et al.*, 2006). These yields are low comparing with other developing countries.

Among several reasons for low production of cabbage in Bangladesh, several Lepidopterous insect pests such as cabbage semilooper (*Trichoplusia ni*), diamondback moth (*Plutella xylostella*), tobacco caterpillar/prodenia caterpillar (*Spodoptera litura*), cutworm (*Agrotis ipsilon*), cabbageworm (*Hellula undalis*) are major limiting factors (Butani and Jotwani, 1984, Bhat *et al.*, 1994). Among these insect pests, *Spodoptera litura* Fab. (Lepidoptera: Noctuidae) is the most destructive pest, which destroys the leaves of cabbage by making holes in the cabbage head and greatly reduces the market value (Butani and jotwani, 1984). With the other polyphagous insects such as *Plutella xylostella*, *Artogeia rape crucevora*, the *Spodoptera litura* (Fab.) became an important pest of vegetables in southern Taiwan (Lee, 1986). Among these insect pests, tobacco caterpillar can cause more than 50 percent reduction of cabbage yield in some cabbage genotypes (Bhat *et at*. 1994). Ahmed (2008) reported that cabbage caterpillar caused damage 3.99% to 13.44% on leaves and 23.33% to 58.33% on plants depending of the varieties of cabbage. Damage caused by the Diamondback moth (DBM), *Plutella xylostella* L. (Lepidoptera: Plutellidae) on head cabbage was assessed and yield losses up to 12 and 20.7 tons/ha in the first season and 27 and 48.7 tons/ha, respectively in the second season (Bhatia, 1994). Yield loss (up to 30%) due to competition may be tolerable as an alternative to severe pest damage, in situations where infestation levels are high (Andrea, 2006). These insect pests cause more serious damages on cabbage in summer season.

The farmers of Bangladesh use chemical insecticides indiscriminately to combat these insect pests of cabbage without considering doses and negative impact of insecticides on non-target organisms, and economic injury level of the pests. These insecticidal controls of the insect pests of cabbage is not only expensive but also the left over residues on the sprayed surface of the crops or in the soil, destroying natural enemies have become a matter of great concern of human health and environmental pollution (Rikabdar, 2000). This is the prime crisis of vegetable growers over the country. Considering the hazardous impacts of chemical insecticides, the utilization of bio-control agents is safe and hazards free tactic for the environmental pollution free management of insect pests (Hasan *et al*., 1960). Among which, parasitic wasps viz. *Trichogramma sp.* an egg parasitoid is the new introduction in Bangladesh against Lepidopterous insect pests of crops. Many parts of the world use *Trichogramma sp.* successfully for crop production against Lepidopterous insect pests. Trichogramma species are facultative gregarious, entirely polyphagous egg parasitoids that are often used in inundative biological control programs against a wide range of Lepidopterous eggs that are totally eco-friendly and non-toxic to the consumers. The inundative releases of egg parasitoid *Trichogramma evanescens* Westwood (Hymenoptera: Trichogrammatidae) adults into commodity could play an important role in suppression of

Lepidopterous moth populations (Brower, 1983) especially *S. cerealella Corcyra cephalonica*); *Helicoverpa armigera*; Mediterranean flour moth, *Ephestia kuehniella*. The egg parasitoid *Trichogramma* can achieve a level of control that is near 100% in some years and/or areas (Rashid *et al*., 2006). But only few works have been initiated in Bangladesh. Alam *et al*. (2008) reported in Bangladesh that significantly highest egg parasitism was done by *T. evanescens* (88.6%) than *T. chilonis* (77.6%) and T. japonica (43.8%) when reared on host eggs *S. cerealella*. Ali (2011) reported that 91.4% parasitization of rice moth, *Sitotroga cerealella* (Lepidoptera: Gelechiidae) eggs had been achieved with the release of *Trichogramma evanescens* egg parasitoid in the laboratory condition at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Ahmed (2008) also reported the 73.64% dead heart and 82.34% white head infestation caused by rice stem borer, *Scirpophaga incertulas* (Lepidoptera: Pyralidae) had been reduced over control by the release of *Trichogramma evanescens* egg parasitoid in the rice field at Sher-e-Bangla Agricultural University, Dhaka. The growers of Bangladesh are far behind the use of bio-control agents like *Trichogramma* for the safe management of Lepidopterous insect pests of cabbage and even they are not yet familiar with them.

Considering the above facts this experiment has been undertaken with the following objectives:

OBJECTIVES

- To find out the level of infestation of cabbage by lepidopterous insect pests,
- To evaluate the effectiveness of *T. evanescens* for the management of Lepidopterous insect pests in the field of cabbage,
- To increase the use of bio-control agent to keep environment friendly.

CHAPTER II

REVIEW OF LITERATURE

Cabbage is an important vegetable crop in Bangladesh, but the crop cultivation faces various problems including the pest management. Among the insect pests, lepidopterous insects are the major pests of Cabbage. *Trichogramma evanescens* egg parasitoid can be used as an important tool to control these insect pests biologically and eco-friendly but considerable literature dealing with reducing infestation of lepidopterous insect pests of Cabbage, performances and effectiveness of biological control treatments such as *Trichogramma evanescens* are very limited. An attempt has been taken in this chapter to review the pertinent research work related to the present study. The information is given below under the following headings:

2.1. Different aspects of lepidopterous insects are presented below:

2.1.1. General review of cabbage semi-looper

The Cabbage Looper (*Trichoplusia ni*) is a member of the moth family Noctuidae belongs to the Order of *Lepidoptera*. It is found throughout the southern Palaearctic ecozone, all of North America, parts of Africa and most of the Oriental and Indo-Australian region.

A. Origin and distribution of cabbage looper

The cabbage looper *Trichoplusia ni* is native to the United States and feeds on many vegetable plants including all members of the cabbage family (Brassicaceae). This insect cannot over winter in the Midwest. Adult cabbage looper moths annually migrate to the Northern United States and Canada from early July to late August, depending on the weather and airflow patterns. There can be 1 to 3 generations during the growing season in the northern states depending on arrival time and late summer temperatures (Hutchison *et al*., 1999).

The cabbage looper (*Trichoplusia ni*) is found throughout North America. It is a major pest of crucifer crops including cabbage, broccoli, and cauliflower may also be found feeding on other agricultural crops such as beets, celery, lettuce, peas, spinach, tomatoes and flowers including carnations and nasturtiums. Cabbage looper cannot survive Canadian winters. Every year, they migrate from the southern US and arrive here in July and August depending on temperatures and wind patterns. Although they normally produce two to three overlapping generations in a growing season, the actual number depends on when they arrive in Canada. It takes approximately one month of warm weather for the cabbage looper to complete its life cycle and produce the next generation of offspring (Dedes, 2003).

Cabbage looper is one of the most important annual pests for Florida cabbage growers. It is less of a problem in southern Florida, where it is considered a minor pest. In that part of the state, pheromone trap data show that adult populations tend to be highest during the late spring and summer months, and in some years in the late fall (Nuessly & Hentz, 1999). Cabbage looper does not enter diapause and cannot survive prolonged cold weather. The insect remains active and reproduces throughout the winter months only in the southern part of Florida (south of Orlando) (Capinera, 1999a). In central Florida, cabbage looper populations peak during early fall and again during late spring (Leibee, 1996). In general, cabbage looper is more of a problem on Florida cabbage during the fall than during the winter or spring months.

B. Life cycle

Cabbage looper do not require an overwintering period as a part of their life cycle, in fact, conditions colder than 10°C can prove fatal. Once adults migrate into an area, they deposit their eggs on the upper or lower surface of host foliage. Eggs are hemispherical in shape, yellowish-white to a light green in color, bearing longitudinal ridges and are approximately 0.6mm in diameter. They are usually laid individually but may be found in masses containing 2-10. The length of time required for eggs to hatch is temperature dependant. Eggs hatch after three days at 27°C or 10 days at 15°C into small, green, first-instar larvae that are initially hairy but lose this hair as they develop. They will shed their skins and moult through a total of five larval stages know as instars. Larvae are light green with faint white stripes running dorsally along their bodies. Their torso at the anterior end is narrow, containing three pairs of forelegs, gradually getting wider to the posterior end with three pairs of prolegs. Larvae move by holding on with their prolegs, projecting their front end forward, grabbing hold with their forelegs and then arching their bodies bringing the prolegs up to meet the forelegs. This method of locomotion is characteristic to loopers, which are also sometimes referred to as “inchworms”. Larvae feed for two to three weeks on the underside of leaves, damaging and killing plants by chewing large holes between plant veins. Mature larvae reach lengths of 3-4 cm before they pupate within fragile, thin, white cocoons attached to the stems or undersides of leaves. Pupae are initially green but as they develop they turn dark-brown or black in colour and are about 2cm in length. Development of adults within pupae takes about six days at 27°C after which they emerge as mottled greyish-brown moths with distinctive silvery markings on their forewings. Adults are considered to be semi-nocturnal and may be active at dusk and during cloudy days but are most active late in the evening. Moths are capable of living up to 200 km to locate new crops where females produce 300-600 eggs to initiate next generation (Dedes, 2003).

Eggs arc deposited singly or in small clusters on either leaf surface, although more are found on the lower leaf surface. Each female moth can produce 300 to 600 eggs during the approximately 10 to 12 days it is alive. After the eggs hatch, additional larvae move to the lower leaf surface to feed. Two to four weeks after hatching, the mature lama forms a thin cocoon on the lower leaf surface, or in plant debris or soil. The pupal stage lasts approximately two weeks. Total time required for development from egg to adult can be as little as 18 days at 21ºC (69.8°F) and 25 days at 32°C (89.6°F) (Capinera, 1999a).

Cabbage looper can be a serious mid- and late season pest of cabbage and other crucifers. They do not over winter in NY; adults migrate into the state during July and August. The adults are about l to l inches across, gray-brown, and fly and lay eggs mostly at night. Eggs are laid singly on the underside of the foliage. The larvae are light green, with a white stripe on each side, about 1 inch long, and move by humping their back like an inch-worm, hence the name “looper”. There may be 2 or 3 generations per year. As the larvae grow, they become more difficult to control (Shelton, 1994).

C. Nature of damage caused by cabbage looper

Cabbage looper larvae damage plants by chewing holes in leaves. Smaller larvae remain on the lower leaf surface, while larger larvae produce larger holes throughout the leaf. In addition to feeding on the wrapper leaves, cabbage loopers may bore into the developing head. Some defoliation can be tolerated before head formation, but feeding damage and excrement left behind on heads make cabbage unmarketable. Cabbage with damage confined to wrapper leaves is marketable but with reduced value. Control has been shown to he justified in Texas when population densities reach 0.3 larvae per plant (Capinera, 1999a). In Florida, an action threshold of 0.1 medium to large cabbage looper larvae per plant was developed for cabbage (Leibee, 1996).

2.1.2. General review of diamond back moth

The diamond back moth, *Plutella xylostella* belongs to the order Lepidoptera and the family Plutellidae.

A. Origin and distribution of diamond back moth

The larval stage can range from ten days to a month, depending on temperature. Diamondback moth larvae slow their feeding at temperatures below 50°F (10°C), and population growth is most rapid at temperatures greater than 80°F (26.7°C). The pupal stage is passed within a transparent, loose cocoon, which is usually attached to the underside of leaves. Within about one to two weeks of entering the pupal stage, the moths emerge (Hayslip *et al*., 1953).

In southern Florida, diamondback moth is most abundant from December to February or March and can attack at any time during the crop cycle. By the end of May, moth counts in pheromone traps fall to near zero. Moth counts may rise in mid-fall through early winter, but activity is limited during that time. Populations build on winter weeds, such as wild mustard, before moving into winter and early spring cabbage plantings. From mid-winter through the spring, when it is a serious pest, diamondback moth may cause losses of up to 70 percent in the absence of control (Nuessly & Hentz, 1999).

The Diamondback moth (*Plutella xylostella*), sometimes called cabbage moth, is a European moth believed to originate in the Mediterranean region that has since spread worldwide. The moth has a short life cycle (14 days at 25°C), highly fecund and capable of migrating long distances. It is one of the most important pests of cole crops in the world and will usually only feed on plants that produce glucosinolates (Talekar and Shelton, 1993).

B. Life cycle

Eggs are laid in groups of 1-6 on the lower surface of the leaf. Moths can lay up to 300 eggs. The eggs are very small and difficult to spot. The larvae that emerge from the eggs, start feeding on the underside of the older leaves of mostly older plants; but will also feed on the young growing points of seedlings. The larvae can reach maturity in between 10 and 14 days in summer and in winter it takes a bit longer. The larvae can go through up to 5 instars before going over to pupating. Pupation can take place on the underside of the leaf or under debris in the soil. The new generation of moths can emerge as quickly as 1 week after pupating. The whole cycle can be completed in 3 to 4 week. Diarnondback moth adults can migrate from southern states into NY in late April and May but the majority of the problem appears to be diamondback moth which enters the state on southern-grown transplants. While diamondback moth does not over winter in upstate NY, it does over winter on Long Island in most years.

Eggs are laid singly or in groups of two or three on the underside of lower leaves or stems. After hatching, larvae pass through four instars stages over a period of 14-30 days. The pupa develops within a loosely spun cocoon attached to the leaves and stems of plants. Adults emerge in 7-15 days. Four to six generations can occur per season. Hot dry conditions favor survival and reproduction, making control difficult (Moyer, 1999).

C. Nature of damage caused by diamondback moth

The larval stage of the diamondback moth (DBM) makes numerous small holes in the leaves, and sometimes leaves fine webbing in the center of the plant. Foliar injury lowers the quality of the crop, and weakens the plant. The larvae themselves can be a contaminant of the final product. Of the three lepidopteron pests of cabbage, DBM is by far the most difficult to control in NY (Moyer, 1999). It usually devours only a small portion of leaf. Larvae work on the underside and eat many small holes. Frequently they leave only the upper epidermis, which has an isinglass-like effect (Janmaat, 2003).

2.1.3. General review of tobacco caterpillar

The tobacco caterpillar, *Spodoptera litura* belongs to the order Lepidoptera and the family Noctuidae.

A. Origin and distribution of tobacco caterpillar

The tobacco caterpillar is found throughout the tropical and subtropical parts of the world. It is wide spread in India (Atwal, 1986). This pest has been reported from India, Pakistan, Ceylon, Burma, Thailand, Malaysia, Cambodia, Laos, Vietnam, Sabah, Indonesia, the Philippines, Taiwan, Queensland, New South Wales, New Guinea, Papua. West Iran. Solomon Islands, Gilbert Islands, New Caledonia, Fiji, Samoa, Tonga. Society Islands, Gilbert Islands and Micronesia (Grist and Lever, 1989). “The two old world cotton leaf worm species *Spodoptera litura* and *Spodoptera littoralis*, are allopatric, their ranges covering Asia and Africa, respectively (Hill, 1983).

B. Life cycle

The population dynamics of *Spodoptera litura* was studied by Zhang *et al*., (2006) by establishing its continuous generation life table. The cumulative death rates of first, second, third, fourth and fifth generations were 93.6, 98.5, 97.2, 99.1 and 99.99%, respectively. The indexes of population trend of the first, second, third, and fourth generations were 17.41, 4.62, 5.63, and 0.55, respectively. This study determined development lasting periods of different metamorphosis for the first, second, third, forth, and fifth generations of *Spodoptera litura*. The emergence sizes and emergence periods of *Spodoptera litura* were predicted using the life table.

Kharub *et al*., (1993) observed that a peak lanal population of *S. litura* on the ground nut cultivar MH4 (Spanish bunch) appeared after 41 weeks. The maximum (38.8°C) and mini mum, (18.6°C) temperature and 61% RH were conducted for the development of larvae of *S. litura* under field conditions. They also found that at 28 ± 2°C in an incubator *S. litura* completed sixth instars in 3.0, 3.7, 5.5, 4.6, 4.1 and 5.6 days respectively. The male and female papal period was 8.6 and 8.4 days, respectively. Males survived for 8.8 days and females for 9.7 days. Copulation took place during the night 3 to 5 times in a lifetime. The female laid an average of 1618.8 eggs (81.82% hatchability) in 12 egg masses in a period of 4.0 days. The incubation period was 3.0 days. In a normal population, the sex ratio (male: female) was 1:0.76.

Kumar *et al.*, (1992) stated that the egg stage duration of the noctuid *S. litura* on sunflower in the laboratory was 3 days in May-June and 5.4 days in October. The duration of the larval stage averaged 15.09 days in June and 16.67 days in October. Larval survival varied from 72 to 92% in May October. The duration of the pupal stage averaged 7.49 days in September and

12.26 days in October. The adult life span averaged 4.1-6.2 days in males and 5.1-7.8 days in females. Studies at constant temperature of 20, 25 and 30°c showed the egg stage last for 5, 4 and 3 days, respectively.

C. Nature of damage caused by tobacco caterpillar

Tobacco caterpillar *Spodoptera litura* attacked the tender leaves, larva caused the damage only. The female moth of cabbage caterpillar laid eggs on the lower surface of the leaves. After hatching of the eggs, the tiny caterpillar starts feeding on host plant. In the early stage of cabbage that was the head forming stage the infestation was found to occur which caused a greater damage. In this stage caterpillars bored the new forming head and reached to the newly emerging little leaf and consumed it. As a result main head of cabbage could not form and at that time it was not economical to replace it with another new seedling. Due to the cosmetic nature of cabbage, a hole is enough to devaluate it. In market it is sold in reduced price. Because of the excreta was left at the damaged site sometimes it caused rotting in the inner portion of cabbage. The nature of damage and extent of damage differed with age of the caterpillars. The young caterpillar along with mature caterpillar also caused greater damage if the infestation occurred at the head forming stage. In field, later stage of cabbage was not found to be infested. Succeeding generations can do greater damage and later instars larvae remained outside the cabbage head, can come out as a serious phase of infestation for their voracious eating habit (Tofael, 2004).

2.1.4. Cutworm

Cutworms are the larvae of several species of night-flying moths (Order *Lepidoptera*, family *Noctuidae*).

A. Origin and distribution of cutworm

Cutworms are a common pest of many vegetable crops including carrots, celery, lettuce, onion, tomato, pepper, eggplant, cole crops, rutabaga, beans, cucurbit crops, sweet corn and several others. Most species of cutworms are solitary feeders found in the soil; however some species occasionally attack the foliage and/or fruit of some vegetable crops (Bentley *et al.* 1996).

There are many species of cutworms attacking a wide range of cultivated and wild plants. Cutworms commonly found in Canada include the black cutworm, *Agrotis ipsilon*; variegated cutworm, *Pedridroma saucia*; dark-sided cutworm, *Euxoa messoria*; dingy cutworm, *Feltia jaculifera*; glassy cutworm, Crymodes devastator; red-backed cutworm, *Euxoa ochrogaster*; black army cutworm, *Actebia fennica*; and white cutworm, *Euxoa scandens* (Flaherty *et al.* 1992).

The black cutworm and the variegated cutworm are the 2 most common species attacking vegetables although other species may be present in some areas. Recognizing damage from cutworms is relatively simple when plants are small. Seedlings are often 'cut' off at ground level and if the soil around the plants is dug up to a depth of about 5 cm, the characteristic cutworm larva can often be found. Cutworms generally curl up as illustrated when disturbed. Cutworms feed at night and will not generally be observed on plants or on the soil surface during the day (Bentley *et al.* 1996).

Black cutworms are grey to black with no striping on the body whereas variegated cutworms are usually brown on the upper surface and cream-coloured on the lower surface. Variegated cutworms also have a row of yellow spots down the back. The red-backed cutworm has a reddish-brown, translucent stripe down its back giving it a distinct appearance. The dark-sided cutworm is a grey-brown cutworm that has distinct striping along the sides giving it a darker appearance. The glassy cutworm has a greenish-white body with a translucent appearance and a pale red head. The black army cutworm feeds in groups unlike the other species and is characterized when small by having a very dark, velvety-black body with faint white striping. As the black army cutworm matures it becomes brown with pale yellow stripes (Bentley *et al.* 1996).

Identification of cutworm adult moths may be difficult without the assistance of a crop specialist or trained entomologist. Cutworm moths are generally dark grey-brown moths with varying mottled patterns or spots on their forewings. Most species have grey-brown-buff hind wings (Flaherty *et al.* 1992).

B. Life cycle

Cutworm leads a complete metamorphosis. Most species pass the winter in soil or under garden trash as young larvae. In the spring, as temperatures warm, they become active and begin feeding on plants at night, remaining hidden during the day. The larvae molts several times and when fully grown pupate in the soil (late spring). Within one week moths emerge and begin laying hundreds of eggs mostly on stems and leaves. One to five generations per year, depending upon the species (West *et al.*, 1990).

C. Nature of damage caused by cutworm

Cutworms overwinter as eggs, larvae, pupae or adult moths depending upon the species. Not all cutworm species overwinter in Ontario during normal winters. For instance a large proportion of the variegated cutworm population is thought to migrate into Ontario each season. Cutworms have 1 to 4 generations per year depending upon the species and location. The majority of cutworm damage occurs to seedling vegetables early in the season and when plants are small. Moths lay eggs on the soil and the larvae hatch to feed on plants. Weedy areas, fields of grasses or pasture are ideal sites for cutworms to overwinter. It is often in these areas and along field borders where problems arise. If weeds are permitted to grow in the fall after crop harvest and the fall and winter seasons are mild, large numbers of cutworms may survive to attack vegetables in the spring (West *et al.*, 1990).

Some species of climbing cutworms lay eggs in groups on the leaves of plants and the larvae hatch out to begin feeding on leaves, flowers and fruit of some vegetables. Late season species, such as the variegated cutworm, often do more damage to mature vegetable plants and their marketable portions. Damage to celery from climbing cutworms can be severe. Variegated cutworms also damage tomatoes when fruit is maturing, leading to serious losses. Damage to other vegetables is normally less severe or noticeable, however peppers, radishes, rutabagas and lettuce may experience limited damage from climbing cutworms (West *et al.,* 1990).

2.2. Control measures against lepidopterous insect pest of cabbage

2.2.1 Cultural control

Cultural controls that can reduce pest populations consist of a variety of management practices such as crop rotation, cultivation, weed management, water management, and proper fertilizer use. Using fallow periods and crop rotation can interrupt the life cycles of pests whenever possible. Always destroy plant debris that can harbor pests and control weeds because they attract insects that may feed on vegetables.

Intercropping is the practice of' increasing crop diversity' by growing more than one plant species in a field to overcome insect pest outbreak problems associated with monocultures. Dempster (1969) studied the effects of weed control in brussels sprouts on P. rapae and found that weeds provide a habitat for predators of the caterpillar. However, yield reduction due to weed competition outweighed the advantageous effects of insect control obtained in the weedy plots. Buranday and Rarest (1975) compared the abundance of adults and oviposition of *P. xylostella* in a cabbage field and in a field with cabbage and tomato intercropped. Both factors were lower in the intercropped field and it was suggested that volatile compounds emitted by the tomatoes repelled the adult moths. The recommended planting pattern is two cabbage rows between two rows of tomato. The pest control benefits' with respect to reduction in larval feeding damage were not assessed as plots were sprayed regularly with *B. thuringiensis*, masking any affect of tomato on larvae. In another study,: numbers of *P. xylostella* larvae and pupae were reduced by intercropping cabbage with tomato, barley, dill, garlic, oats or safflower (Talekar *et al*., 1986).

Kenny and Chapman (1988) assessed an intercrop of cabbage and dill (*Anethum graveolens* L.). The number of cabbage aphids on cabbages planted near dill was lower than those planted without dill. Results for numbers of *P. rapae* and *Plutella xylostella* and damage measurement were inconsistent due to low pest populations. Competition from dill was found to reduce yield, but a different planting arrangement could overcome this problem.

2.2.2 Mechanical control

Mechanical control is the use of physical means to reduce the number of insects or insect damage or to exclude pests from the crop field. Mechanical methods include the use of barriers, covers, high pressure water sprays, and hand picking of pests. Barriers come in many shapes and sizes. They prevent the movement of pests onto the plants. Cardboard or plastic cylinders around the base of transplants are an example of a barrier that discourages cutworms and other soil-inhabiting pests from attacking transplants. Cloth or plastic row covers can serve as a cover to keep out pests in a crop field. Screening may increase the temperature of a planting bed, so additional benefits of temperature management may be achieved. Screening is useful for young plants and seedlings that are the most susceptible to pest attack. High pressure water sprays are also a mechanical control method. Sprays are most effective against small, soft-bodied pests like aphids. High pressure water sprays may help remove webbing, dissolve droppings, and quickly reduce the number of pests.

Talekar *et al.*, (1986) found that sprinkler irrigation applied to cabbage for five minutes at dusk throughout the life of the crop physically disrupted diamondback moth flying activity and oviposition and drowned larvae and adults. Such a modification of a cultural practice could be a valuable component of a pest management system.

The use of lightweight netting row covers, as a barrier to oviposition, is another effective non-chemical insect control technique. Row covers are mainly used to extend the growing season and by protecting against frosts provide early vegetables by decreasing time to maturity (Mansour, 1989) and they are also effective as barriers against *P. rapae* and *P. xylostella*.

2.2.3 Chemical control

In controlling moths still mostly are used organic phosphorus esters. In this group classified active compounds are chlorine pirifos-methil, phenitrotion and acephate (Pelosini, 1999). Sufficient efficacy in this relation can attain also with pyrethroids (cypermethrin, deltamethrin, lambda-cyhalothrin, betacyfluthrin and tefluthrin). In Slovenia registered products for controlling cabbage moth are from a group of pyrethroids, a product on the basis of pyrethrin, a product which corresponds to oxadiazine and one from the group of insect development inhibitors (IRI). Pyrethroids which are registered in Slovenia are Fastac 10 % SC (alfa-cypermethrin) and Karate Zeon 5 CS (lambda-cyhalothrin). Two products are also used when controlling cabbage moth, namely pyrethrin (Spruzit powder) and indoxacarb (Steward). Active ingredient indoxacarb refers to the group of oxadiazines which is also advanced one. Insecticides from the oxadiazines group block Na-channels in nerve fibers. Target insects stop feeding, stay paralyzed and die soon. Product Steward is suitable for integrated production. Chitinase inhibitors display minor danger for human being and are suitable especially for controling eggs and young larvae (Corvi and Nardi, 1998). Among inhibitors of insect development active ingredients are teflubenzuron, esaflumuron and lufenuron (Pelosini, 1999). The last one is registered in Slovenia and represents an active ingredient of product Match 050 EC.

If there are caterpillars of various developmental stages on the ground, Corvi and Nardi (1998) recommend the application of pyretroids or carbamates. Both groups of insecticides belong to neurotoxins and act as a contact or stomach insecticides. In case of cabbage moth control in autumn, Corvi and Nardi (1998) advice double treatment with synthetic insecticides (pyretroids, carbamates, organic phosphorus esters and growth regulators) and at least spraying with microbiological products on the basis of *Bacillus thuringiensis* var. *kurstaki*.

2.2.4 Biological control

Biological control includes use of natural enemies/biological control agents to regulate cabbage butterflies. Three well known biological control agents including *Bacillus thuringiensis* (Bt), entomopathogenic nematodes and wasps have a potential to manage cabbage butterfly population in the vegetable gardens and fields.

2.2.4.1 *Bacillus thuringiensis kurstaki* (Bt)

This bacterium is recognized as a bacterial insecticide but it is not harmful to the humans, animals or the environment. This is a very effective biopesticide on young larval stages as compared to the mature larval stages of cabbage lepidopterous insect pests. This microbial biocontrol agent is commercially available and can be applied using traditional sprayers. For the effective control of cabbage lepidopterous insect pests, *Bacillus thuringiensis kurstaki* should be applied at every seven day interval after noticing the first incidence of pest.

2.2.4.2 Entomopathogenic nematodes

Currently, entomopathogenic nematodes are used as effective biological control agents against many different kinds of soil-dwelling insect pests of many economically important crops and turfgrasses. These nematodes are commercially available and are not harmful to humans, animals and even beneficial insects like honeybees. Canadian researchers have demonstrated that the entomopathogenic nematodes including *Steinernema carpocapsae*, *S.*

feltiae and *S. riobrave* can cause 76 to 100% mortality of cabbage butterflys *Artogeia rapae* if applied at temperatures ranging from 25 to 30 °C and their LC50 values were ranged from 4 to 18 infective juveniles (Bélair *et al*., 2003). Mahar *et al.*, (2005) also reported that in addition to the above stated species of entomopathogenic nematodes, *Heterorhabditis bacteriophora* and *H. indica* nematodes can infect and kill both larvae and pupae of cabbage butterflies. Recently, another insect-parasitic nematode, *Rhabditis blumi* also been shown to be effective against cabbage butterfly (Park *et al*., 2012).

2.2.4.3 Wasps

A various species of parasitic wasps can serves as effective biological control agents against lepidopterous insect pests of cabbage. The egg parasitic wasp, *Trichogramma spp.* is the most effective egg parasitoid against lepidopterous insect pests of cabbage.

2.2.4.3.1 *Trichogramma*

Trichogramma is a potential biological control agent against lepidopterous insect pest. It is an egg parasitoid that kills the pest before it can cause any damage to the plant. *Trichogramma* are among the smallest insects, having a wingspread of about 1/50th of an inch. Despite its size, this parasitic wasp is an efficient destroyer of the eggs of more than 200 species of moths and butterflies which are leaf eaters in the larval stage. *Trichogramma* wasps seek out eggs, but do not feed on or harm vegetation. It is a particularly effective control agent because it kills its host before a plant can be damaged.

2.2.4.3.2 Taxonomic position

Phylum: Arthropoda

Class: Insecta

Order: Hymenoptera

Family: Trichogrammatidae

Genus: *Trichogramma*

2.2.4.3.3 Species and identification

Within the genus *Trichogramma*, there are 145 described species worldwide; 30 species have been identified from North America and an estimated 20 to 30 species remain to be described. The species most commonly collected from crops and orchards are *evanescence, atopovirilia, brevicapillum, deion, exiguum, fuentesi, minutum, nubilale, platneri, pretiosum,* and *thalense* (Olkowski and Zhang, 1990). *Trichogramma* are difficult to identify because they are so small and have generally uniform morphological characters. Also, certain physical characteristics such as body color and the number and length of body hairs can vary with body size, season, rearing temperature and the host on which the adult was reared. Because of these difficulties and the lack of type specimens, species names in the literature in North America prior to 1968 were used incorrectly and inconsistently and are therefore unreliable.

2.2.4.3.4 Biology and life cycle

Adults are approximately 1/25 inch (0.1-1.2 mm). They often have wing hairs (setae) arranged in rows. Their body is relatively compact and the antennae are short. *Trichogramma* species are difficult to identify due to their minute size and generally uniform morphological features. *Trichogramma* spp. undergoes complete metamorphosis. The adult wasp lays an egg within a recently laid host egg, and as the wasp larva develops, it eats the host embryo, causing the egg to turn black. Because their life cycle from egg to adult is about 7 to 10 days, these parasites have many more generations than their hosts and their populations can increase rapidly. *Trichogramma* turns the eggs of some caterpillar species black (Olkowski and Zhang, 1990). This is the best way to detect parasitization by *Trichogramma*. *Trichogramma* wasps primarily parasitize eggs of moths and butterflies (Lepidoptera). However, certain species of *Trichogramma* also parasitize eggs of beetles (Coleoptera), flies (Diptera), true bugs (Heteroptera), other wasps (Hymenoptera), and lacewings and their relatives (Neuroptera). The adult female wasp uses chemical and visual clues to locate host egg. The chemical clues, called kairomones, are on the moth scales left near the egg by the female moth during oviposition. Some of these same chemicals are also sex pheromones of the host. Egg shape and color also may be visual clues to the wasp. Once a female finds host egg, she drills a hole through the chorion (egg shell) and inserts two to three eggs into the host egg. The internal pressure of the host egg forces a small drop of yolk out of the ovipositor hole. Females feed on this yolk, which increases their longevity. Under laboratory conditions a female parasitizes from one to ten host eggs per day during her life. Large females parasitize more eggs than smaller females. Females provided honey and young host eggs to feed on live an average of 11 days, while females receiving only honey live 3 days. Host eggs in the early stages of development are more suitable for parasite development. Older eggs, especially those in which the head capsule of the larva is visible, are not usually parasitized and if they are, parasite survival is much lower. The yolk and embryo of the parasitized host egg are digested before the *Trichogramma* egg hatches. Venom injected by the female at the time of oviposition is believed to cause this predigestion of the egg's contents. Eggs hatch in about 24 hours and the parasite larvae develop very quickly. Two *Trichogramma l*arvae can consume the digested contents of a young budworm egg within 10 hours of hatching (Strand, 1986). Larvae develop through three instars. During the 3rd instar (3 to 4 days after the host egg was parasitized) dark melanin granules are deposited on the inner surface of the egg chorion, causing the bollworm egg to turn black. Larvae then transform to the inactive pupal stage. After about 4-5 days, the adult wasps emerge from the pupae and escape the bollworm egg by chewing a circular hole in the egg shell. The black layer inside the chorion and the exit hole are evidence of parasitism by *Trichogramma.* The life cycle from egg to adult requires about 9 days, but varies from 8 days when mid-summer temperatures are high (90°F) to as many as 17 days at 60° F. Adults are most active at 75 to

85° F. An average of two *Trichogramma* adults will emerge from a single egg of host. A single host egg can yield wasps of the same or opposite sex. *Trichogramma* adults emerge from host eggs in the early morning. Males emerge first and remain at the host egg to mate with emerging females if they are present. Mated females produce male and female offspring. Unmated females produce only males. Females begin egg laying within a few hours of emergence. *Trichogramma* overwinter as immature forms in host eggs. Some species enter a state of diapuase which allows them to tolerate long periods of subfreezing temperatures. Other species of *Trichogramma*, slow their rate of development and may be active as adults during warm days as early as January and February (Matthias and Sherif, 2001).

2.2.4.3.5 Identification of different species of *Trichcgramma* - described by Alba (1986) as follows:

Trichogramma chilones Ishee. Male yellow with blackish abdomen and mesoscutum. Antennal hairs somewhat sharply tapering and moderately long; forewing with 4 to 6 oblique lines setae (R_{S1}); fringe on tornus about one sixth width of wing. Genitalia with dorsal expansion of gonobase triangular, with lateral lobes very prominent, chelate structure (CS) markedly below level of gonoforceps, median chitinized ridge (CR) paired, extending anteriorly to about-two-thirds length of genitalia; aedeagus as long as apodemes, both slightly shorter than hind tibiae. Female yellow with first three abdominal terga black; antennae clubbed with short hairs on flagellum. Ovipositor as long as or slightly longer than hind tibiae. *Trichcgramma chitotraeae* Nagaraja and Nagarkatti. Male yellow with blackish pronoturn, mesopleurum, mesoscutum, abdominal terga and hind coxae; antennal flagellum augmented with long hairs, longest hair more than three times the maximum width of flagellum; forewings with 3 to 4 obliquely lined setae (R_{S1}). Genitalia with more or less triangular dorsal expansion of gonobase (DEG), apex tapering and not projecting beyond gonoforceps (GF), but extending only to level of chelate structures

(CS); aedeagus prominent and long projecting beyond gonoforceps (almost as long as or slightly longer than the entire male genitalia); large chelate structures for below level of tips of gonoforceps (GF), protruberance at base of chelate structures very minute and inconspicuous; median ventral projection (MVP) very distinct and long, with two continuous ridges (CR) extending anteriorly only for a short distance from median ventral projection (MVP) adages together with apodemes slightly shorter than hind tibia. Female yellowish on anterior part and most of mesoscutum, one or more penultimate abdominal terga in median region blackish; antennae typically clubbed with few short hairs. Ovipositor slightly longer than hind tibia (Alba, 1986).

Trichcgramma evanescens Westwood Male dull brownish yellow with black thoractic sclerites and abdominal terga; antennal hairs long and sharply tapering; longest hairs about three and one half times maximum width of flagellum; forewings with 8 to 9 oblique lines setae (R_{s1}) with fringe on tornus nearly one fifth width of wing, fringe on outer margin as well as on tornus nearly of equal length. Genitalia with dorsal gonobase expansion (DEG) highly sclerotized, horseshoes-shaped with blunt posterior extremity; chelate structures (CS) far below level of tips of gonoforceps (GF); median ventral projection (MVP) inconspicuous, entire region highly chitinized; median chitinized ridge (CR) paired, extending about two-thirds the length of genitalia, adages distinctly longer than apodemes, both as long as or very slightly longer than hind tibia. Female dull brownish color with black thoracic sclerites; antennae clubbed with few short hairs on flagellum. Ovipositor nearly one and one half times longer than hind tibia (Alba, 1986).

2.2.4.3.6 Using *Trichogramma* in a biological control program

2.2.4.3.6.1 Introduction of new species:

At least four species of *Trichogramma* have been imported to the U.S. and released for the control of crop pests. In 1968, *T. evanescens* was introduced from Europe into southern California and Missouri for control of imported cabbage worm and cabbage looper on cabbage. A species from Russia, *T. euproctidis*, was imported and released in cotton in Georgia in 1975. In 1993, *Trichogrammatoidea bactrae* was introduced from Australia into California and Arizona for control of the pink bollworm in cotton. The establishment of these three introduced species has not been documented. During 1993-96, *T. ostriniae* was imported from China and released in New York for control of European corn borer in sweet corn (Teotimo and Adhikari, 1998).

2.2.4.3.6.2 Augmentation

Augmentation is the periodic release of a natural enemy that does not occur naturally in sufficient numbers to keep a pest below damaging levels. Agumentation can be carried out by inundative releases or inoculative releases. The inundative approach is achieved by flooding the crop with multiple releases of insectary-reared natural enemies. The released insects control pests present at the time, but there is little expectation that later generations will persist at sufficient levels to provide control. This approach requires a large number of the natural enemies at the precise time when pest eggs are present and crop and weather conditions are conducive to the release. Correct timing requires good coordination between the rearing facility and field staff. Inoculative releases involve one or several releases to establish populations of the natural enemy before pest densities have begun to increase. The natural enemy reproduces on the target pest or an alternate host and its population increases to levels sufficient to control the target pest later in the season. In China, inoculative releases of *Trichogramma* in gardens in the spring produce populations of wasps which later in the season move into adjacent fields to control cotton pests (Li, 1994).

2.2.4.3.6.3 Conservation

Conservation as a biological control method includes crop management practices that protect and encourage natural enemies and increase their impact on pests. Examples include using only selective insecticides and planting strip crops in and around fields to provide food and habitat for natural enemies. Insecticides such as Bt (formulations of *Bacillus thuringiensis*) and some insect growth regulators have very little or no impact on *Trichogramma* and can be used in IPM programs with *Trichogramma*. Interplanting rye grass in seed corn production fields lowered soil temperatures which otherwise would be lethal to released *Trichogramma* distributed in cardboard capsules deposited on the soil (Orr *et. al*., 1997). *Trichogramma* species commonly parasitize bollworm (corn earworm) in corn and sorghum, and these crops may serve as an important source of adults which disperse into cotton.

2.2.4.3.6.4 Methods for releasing *Trichogramma*

Trichogramma are typically shipped and released as pupae inside the host egg. Parasitized pupae are distributed in the field just prior to emergence of the adult wasps, although in some Latin American countries wasps are released after emergence. Parasitized host eggs can be mixed with a carrier and broadcast, or glued to cards or the inside of paper capsules which are then dropped onto or attached to the crop. Broadcasting host eggs is relatively simple but host eggs that fall on the ground may be subjected to lethal temperatures or drowns in flooded areas. Also, adults emerging from loose eggs or egg capsules deposited on the ground must walk or fly to the plant to locate host eggs. It is desirable for adults to emerge quickly so they escape predation and avoid high temperatures. Adult emergence can be synchronized to occur shortly after release by refrigerating host eggs at 16.7°C in total darkness beginning on the eighth day of development. After at least 6 days and up to 10 days of refrigeration, adults will emerge within 4 hours once pupae inside host eggs are exposed to light and at least 27^0C. This reduced temperature regime results in about 73 percent of the adults emerging within 4 hours of field release. However, chilling and warming can interfere with development (Stinner *et. al*., 1974). Both manual and mechanized release methods using ground and aerial applicators have been developed. Aerial release methods using refrigeration units were developed in the U.S.A liquid spray system (Biosprayer) is available for ground application.

2.2.4.3.6.5 Mass rearing *Trichogramma* for commercial release

Rearing *Trichogramma* requires first rearing an insect, typically a species of moth, to produce eggs in which the wasps will develop. The Angoumois grain moth, *Sitotroga cerealella*, and the Mediterranean flour moth, *Ephestia kuehniella*, are easily and inexpensively reared on wheat or other grains and are commonly used to rear *Trichogramma* (Morrison, *et. al*., 1987). Studies to date indicate that there is no difference in field performance between *Trichogramma* reared on *Sitotroga* and those reared on *Ephestia*. To lower production costs, research is underway to develop an artificial egg. China has led in this area and commercially produces one species of *Trichogramma* on an artificial diet composed of insect blood. Further research should lead to major reductions in production costs. Poor quality of mass reared *Trichogramma* can result in control failures. The artificial conditions of mass rearing can select for genetic changes that reduce the effectiveness of the *Trichogramma* in the field. Such rearing conditions include rearing multiple generations on unnatural host eggs, the absence of plants, crowding and interference, rapid generation time, and failure to rejuvenate genetic stock. Except for obvious problems such as lack of adult emergence or wing deformities, growers and pest advisors cannot detect poor quality *Trichogramma* prior to release. Commercial suppliers are responsible for maintaining desirable characteristics necessary for good performance in the field. Production colonies should be periodically (i.e., every six generations) replaced with individuals from a stock culture maintained on the natural or target host. Suppliers also should assess the percent host egg parasitization, adult emergence, and the sex ratio of emerged adults to be sure they are within acceptable standards. Standards for established cultures on *Sitotroga* are 80 ± 5 percent egg parasitization, 90± 5 percent adult emergence, and a sex ratio of 1.2 to 1.5 females per male. The Association of Natural Biocontrol Producers and the International Organization of

Biological Control Subcommittee on Quality Control are developing quality control standards for *Trichogramma* and other natural enemies (Teotimo and Adhikari, 1998).

2.3. Biological control status and parasitization performance of *Trichogramma* on different crop pests:

Early cotton entomologists noted that *Trichogramma* parasites commonly attacked bollworm eggs in cotton. Parasitism rates reported in 1903 and 1945 ranged from 5 to 35 percent in Texas cotton, presumably in the absence of insecticides (Quaintance and Brues, 1905). In Arkansas, parasitism of bollworm and budworm eggs in untreated cotton is typically 20 percent (Kring and Smith, 1995). In Louisiana, early season parasitism reached 60 to 80 percent but sharply declined once insecticide treatments began (Johnson, 1985). In the Gulf Coastal region of Texas, natural parasitism of bollworm and budworm eggs in cotton increased from about 20 percent in early June to 65 percent by late July (Segers *et. al*., 1984).

Two releases each at a rate of 185,000 pupae per acre are made beginning at the first moth flight as determined by black light traps in European corn borer. European corn borer eggs hatch after about 5 to 6 days and the egg-laying period continues for 4 to 7 weeks. In-field reproduction of released parasites is believed to be important in providing residual control of eggs deposited after the second release. Field evaluations in Germany have shown releases result in a 70 to 93 percent reduction in corn borer larvae relative to untreated fields (Bigler, 1994). Augmentation of *Trichogramma* has also been promoted for pest control in cotton, corn, apple, spruce and avocado production. However, a recent survey found that very few state Cooperative Extension Services currently provide recommendations for controlling any insect pest with *Trichogramma* (Bigler, 1994).

In California, parasitism of tomato fruit worms (bollworms and budworms) by native *T. pretiosum* in tomatoes is considered in the treatment thresholds for treating these pests with insecticides. Augmentation of *T. pretiosum* is an effective control tactic in Mexico and is part of the IPM program for fresh market tomatoes (Saour, 2004). In California, two avocado pests, the omnivorous looper *Sabulodes aegrotata* and the moth *Amorbia cuneana*, can be managed by releasing *T. platneri* in every fourth avocado tree. Large field studies in Canada have shown that two releases each of 30 million *Trichogramma minutum* per acre resulted in 60 to 80 percent egg parasitism of spruce budworm, *Choristoneura fumiferana*, in white spruce stands. However, *Trichogramma* releases have not been adopted as a control tactic for spruce budworm in Canada (Saour, 2004).

Polaszek *et al.* (2002) reported that *Trichogramma zahiri* Polaszek is described from Bangladesh. It has been recorded as important controlling impact on the eggs of the major pest of rice *Dicladispa armigera* (Olivier).

A mass rearing system for *Trichogramma* spp. using host eggs killed before parasitization could improve current parasitoid production methods by making the system more efficient reported by Ozder (2002). Parasitism rates of *T. cacaeciae, T. evanescens* and *T. brassicae* reared on dead embryos of *E. kuehniella* kept at -20 degrees C during 1, 2 and 3 h were compared. The lowest parasitization rate was obtained on *E. kuehniella* eggs which had been kept at -20 degrees C for 3 h. Parasitization rates were 64, 65.60 and 63.60% for *T. cacaeciae, T. evanescens* and *T. brassicae,* respectively, reared on *E. kuehniella* eggs kept at -20 degrees C for 1 h. Subsequent trials focused on fitness of *T. cacaeciae, T. evanescens* and *T. brassicae* reared on killed embryos of *E. kuehniella*. Percentage of parasitized eggs and longevity of females were quantified. Exposure of eggs to low temperatures in a freezer reduced fecundity and longevity of females.

Grenier *et al*. (2001) reported that the size of some *Trichogramma* spp. adults and especially the ovipositor length depends on the species, but is also related to the host species and to the number of parasitoids per host. The length is greater in *T. evanescens* than in *T. pretiosum* itself greater than in *T. exiguum*, but the width is similar in the three species. For *T. evanescens*, the size obtained in Mamestra brassicae host when three or four insects emerged is similar to that obtained in *Ephestia kuehniella* host when singly parasitized. The size of the ovipositor is important because it may influence the possibility of in vitro egg laying in artificial host eggs. A shorter or a narrower ovipositor could cause difficulties in egg-laying into artificial host eggs composed of a membrane of unsuitable thickness.

Reznik *et al*. (2001) carried out a laboratory experiments with *T. principium* females that were offered *Sitotroga cerealella* eggs demonstrated that less than half of the ovipositing females started oviposition during the first 2 days of the experiment, whereas the rest of the ovipositing females showed a delay in parasitization ranging from 2 to 10 days after contact with the host. Almost 10% of the wasps refused to parasitize the grain moth eggs over 12 days. The delay in parasitization may be as long as 6-8 days without any significant decrease in the number of mature ovarial eggs, in the number of eggs laid during the first 48 h of oviposition, and in the total lifetime fecundity. This egg retention is responsible for the fact that in spite of a relatively short mean duration of the oviposition period in each individual female (approximately 4 days), host parasitization by a group of simultaneously emerged wasps was almost uniformly distributed over 8-10 days. When induced, the parasitization state (i.e. the tendency to parasitize sequentially offered portions of host eggs) was stable both in the presence of a host and under host deprivation extended up to 8 days. These data provide further evidence for our hypotheses that the stability of the parasitization state in Trichogramma is based on endocrine mechanisms.

The *Trichcgramma* pasasitoids and other egg parasites are desirable biological control agents due to the following reasons: (1) they attack and kill a variety of lepidopterous eggs before they can damage the crop; (2) they are relatively specific to the pest species and safe to use; (3) they can establish in a tropical ecosystem and can be integrated with other control strategies; (4) some species are locally available and (5) they can be mass produced cheaply and conveniently on unnatural host *Corcyra cephalonica* Stainton, by the farmers themselves (Cadapan, 1986).

The efficiency of *Trichcgramma* species against some rice insect pests was reported by Perez and Cadapan (1986). The insect pests affected were the eggs of yellow stem borer, *Tryporyza incertulas* (Walker); stripe rice stem borer, *Chilo suppressalis* (Walker); leaf folder, *Sesamia Exiqua* (Butter); *Marasmia patnalis* (Bradley); green semi-looper, *Narangga aenescens* (Morre), rice caseworm, *Nymphula depunctalis* (Greenee).

Accordingly, the degree of parasitization on the different host eggs depends on morphological characteristics of the egg and location on the leaf where egg masses were deposited. Egg masses that were covered with bristle-like silky covering, secreted by the female moth during oviposition, prevented the female parasite from ovipositing her egg. They further observed that the host egg parasite ratio of three spp. of *Trichcgamma* on the different rice pest eggs were related to the size of the host eggs. Larger eggs like the egg of *C. supprelis* accommodate more than one parasite per egg (Rissig *et al.*, 1986).

The potential *of T. australicum* and *T. chilotraeae* against the eggs of *H. armigera* was studied by Torreno and Cadapan (1984), Parasitization and subsequent emergence of adult *T. australicum* and *T. chilotraeae* were found to be highest in newly laid (less than 12 hours) eggs compared to the two and three-day-old eggs of *H. armigera.* As the host egg advances in its embryonic development, it becomes less attractive for parasitization (Torreno and Cadapan, 1984).

A study made by Morales (1991) showed that higher rates of *T. chilones* application increased percent parasitization both for *H. armigera* and *L. orbonalis.* Recommended insecticide application out yielded all other treatments and as expected, the untreated control was the lowest yielder. Although the recommended insecticide significantly performed better in terms of yield, *Trichogramma* treated plants at either 50,000 or 75,000 parasitoids per hectare per release may prove economical considering the high cost of insecticides.

The dissection of papilio larvae parasitized by *Trichogramma papilioni* Nagarkatti and *T. dendrolomi* Matsumura revealed than the females inserted their ovipositor into host eggs but withdraw without laying on eggs of older hosts (Magallona *et al.*, 1977). It was found out that *T. evanescens* preferred eggs of Ostrinia when they were at the vitellus stage (Icayan, 1978). Their rejection for old age egg was most probably due to physical and chemical conditions which cause them to withdraw their ovipositor without laying an egg.

Afroz (2011) worked with *Trichogramma* as an important component of IPM package for the control lepidopteran pest (okra shoot and fruit borer) of okra. In that experiment, *Trichogramma evanescence* egg parasitoid @ 0.5g/plot at 7 days interval treatment always performed better than most of the other treatments resulting the third highest reduction of number of bores per fruit and that was 62.09 %, the third highest 60.0 % reduction of number of larvae per fruit, 72.22 % reduction of fruit infestation by number, 66.11 % reduction of fruit infestation by weight, the third highest length and girth of fruit, 59.17 % increase of total yield of okra.

Rahman (2011) also worked with *Trichogramma* and found similar type of results in case of controlling lepidopteran pest (tomato fruit borer) where *Trichogramma evanescense* @ 0.25g/6m2 at 7 days interval treatment resulting better result in case of lower number of infested fruit by number and also by weight than most of the other treatments used in that experiment.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the experimental farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207during the period from October, 2011 to March, 2012 to evaluate of the effectiveness of *Trichogramma evanescens* for hazards free management of lepidopterous insect pests of cabbage in the field. The details materials and methods that were used to conduct this experiment are presented below under the following headings:

3.1 Location and duration of the project study

The experiment was conducted in the experimental farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period of 2011 to 2012.

3.2 Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during rest months of the year (Rabi season). The average maximum and minimum temperature were 29.45ºC and 13.86º C repectively during the experimental period. Rabi season in characterized by plenty of sunshine. The maximum and minimum temperature, humidity rainfall and soil temperature during the study period were collected from the Bangladesh Meteorological Department (Climate Division).

Plate 1. The experimental plot at SAU, Dhaka

3.3 Land preparation and fertilization

The plot selected for the experiment was opened in the first week of October 2011 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable tilth of soil for transplanting of seedlings. During land preparation 10 t/ha decomposed cowdung were mixed with soil and following fertilizers were applied. Urea, TSP, MP as the source of Nitrogen (N), Phosphorus (P_2O_5), Potassium(K_2O) fertilizers recommended by Rashid *et al.* (2006):

- ❖ Urea : 150 kg/ha
- ❖ TSP : 100kg/ha
- ❖ MP : 125 kg/ha

Urea was applied at top dressing in three equal splits at 10, 25 and 50 DAT.

3.4 Materials used for the experiment

The variety Atlas-70 of cabbage was selected for the experiment and the seeds of this variety were collected from local market.

3.5 Raising of Seedling

Cabbage seedlings were raised at the seedbeds of experimental farm, Sher-e-Bangla Agricultural University, Dhaka 1207 under special care. The seeds of the variety were sown in the well prepared seed bed. All weeds, stubbles and dead roots of the previous crops were removed carefully before sowing of seeds. The seed bed was dried in the sun to prevent the damping off diseases. Five grams of seeds were sown in the seedbed on 30 October 2011. Before sowing seeds, the germination test was done to ensure standard viability measuring approximately 90% germination. Pre-soaked seeds for 24 hrs to ensure germination were sown in the seed bed. After sowing, the seedbed was covered with fine light soil. All seeds were completely germinated within 7 days after sowing. Shading was given by polythene sheet over the seed bed to protect the young seedlings from scorching sunlight and rainfall. Weeding, mulching and irrigation were done from time to time to provide a favorable condition for good growth and raising quality seedling.

3.6 Transplanting of seedling and after care

Healthy and uniform sized 30 days aged seedling were transplanted in the experimental plots on 29th November, 2011 at a spacing 60 cm x 60 cm. Transplanting was done in the afternoon and watered immediately after transplanting. After seedling establishment, the soil around the base of each seedling was pulverized and new ones from the same stock replaced the damaged seedlings. The young transplants were protected from scorching sunlight providing shade with pieces of banana leaf sheath during the day time. At night, they were kept open to allow receiving dew. It was continued up to 5-7 days until they were established in the soil and after that the banana leaf sheaths were removed.

3.7 Experimental design and layout

The study was laid out in RCBD in the experimental field of Sher-e-Bangla Agricultural University, Dhaka with three replications. The plots were filled with cow dung and necessary mixed soils. The field with good tilth was divided into 3 blocks. Each block was sub-divided into 9 sub plots, each of which will be of 3 m x 1 m maintaining 1.0 m borders. The plant spacing was maintained considering 60 cm row to row distance and 60 cm plant to plant distance.

3.8 Treatments of the experiment

T. evanescens egg parasitoids were released in the plots of cabbage field in the form of Tricho Paper Card to evaluate their effectiveness against Lepidopterous insect pests considering the following treatments:

T_1 = Tricho Paper Card @ 0.20 g/plot at 5 days interval

T_2 = Tricho Paper Card @ 0.30 g/plot at 5 days interval

T_3 = Tricho Paper Card @ 0.40 g/plot at 5 days interval

T_4 = Tricho Paper Card @ 0.50 g/plot at 5 days interval

T_5 = Tricho Paper Card @ 0.20 g/plot at 10 days interval

T_6 = Tricho Paper Card @ 0.30 g/plot at10 days interval

T_7 = Tricho Paper Card @ 0.40 g/plot at 10 days interval

T_8 = Tricho Paper Card @ 0.50 g/plot at10 days interval

T_9 = Untreated Control

3.9 Intercultural operations

During the cropping season of the cabbage the necessary intercultural operations were done as described below:

3.9.1 Gap filling

At the time of each transplanting few seedlings were transplanted in the border of the experimental plots for gap filling, very few numbers of the seedlings were damaged after transplanting and such seedlings were replaced by healthy seedlings from the same planted earlier on the border of the experimental plot. The seedlings were transplanted with a mass of soil roots to minimize the transplanting stock.

3.9.2 Weeding

The land of the each plot was kept free from weeds and two times weeding was done. The first weeding was done after 20 days of transplanting and second weeding after 45 days of transplanting. Weeding was done by uprooting and using with mechanical weed control method.

3.9.3 Irrigation and drainage

After transplanting light irrigation was given to each plot. Supplementary irrigation was applied at an interval of 5 days. Stagnant water was effectively drained out at the time of over irrigation.

3.9.4 Earthing up

Earthing up was done in each plot to provide more soil at the base of each plant. It was done 40 and 60 days after transplanting (DAT).

3.10 Application of *Trichogramma* egg parasitoids

Treatments comprising T. evanescens in the form of Tricho Paper Card were released in their respective plots in the cabbage field considering the above mentioned treatments and intervals up to the harvesting stage of the cabbage. After releasing the parasitoids, the respective plots will be bordered with fine mosquito nets to avoid their drift effect.

3.11 Stock culture of *Trichogramma evanescens*

The inoculum of egg parasitoid *Trichogramma evanescens* was collected from the Protegra Agro-Bio Tech Ltd, Mirpur, Dhaka, Bangladesh. There the freshly laid and cleaned *Sitotroga cerealella* eggs were taken and glued on a strip of card sheet (12 inch x 8 inch) in single layer using ten percent gum arabica and these cards were exposed to *Trichogramma evanescence* for 8 to 10 hours to maintain the culture. After 24 hours, the parasitized cards were withdrawn and placed in convenient glass containers or glass vial and stored in the laboratory at ambient room conditions as per design. The open end of the container was closed using muslin cloth fastened by rubber band. The parasitoids that emerged from the cards were released in the selected experimental plots at an interval of 5 to 10 days according to the different treatments.

3.12 Data collection and calculation

The data on level of infestation caused by Lepidopterous insect pests on cabbage, incidence of larvae and adult was recorded for each of the treatments.

3.13 Level of infestation

The number of uninfested and infested leaves and plants of cabbage caused by the larvae of Lepidopterous insect pests was counted. The observations were recorded at the first observation of damage leaves and plants and were continued up to harvesting stage of the cabbage at 7 days interval. The data on the yield was also recorded. The level of leaf and plant infestations per plant and plot respectively was then calculated using the following formula:

$$\text{\% leaf or plant infestation} = \frac{\text{No. of infested leaves or plants}}{\text{Total no. of leaves or plants}} \times 100$$

3.14 Insect infestation percentage on head

The infested heads was calculated at harvesting stages using the following formulae:

$$\text{\% head infestation by number} = \frac{\text{Number of infested heads}}{\text{Total Number of heads}} \times 100$$

$$\text{\% head infestation by Weight} = \frac{\text{Weight of infested heads}}{\text{Total head Weight}} \times 100$$

3.15 Yield

Yield/plot was recorded from the experiment field and then it was converted to total yield (t/ha). Percent increase or decrease of yield over control was calculated by using the following formula:

Percent increase or decrease of yield over control

$$= \frac{\text{Yield of treated plots} - \text{Yield of Control plots}}{\text{Yield of Control plots}} \times 100$$

3.16 Analysis of data

The data collected on different parameters were statistically analyzed using the MSTAT computer package program. Mean values were ranked and compared by Duncan's Multiple Range Test (DMRT) at 5% level of significance (Gomez and Gomez, 1984).

<u>Some Photographs from the Experiment Field</u>

Plate 2. A)Healthy Head B) Infested Head

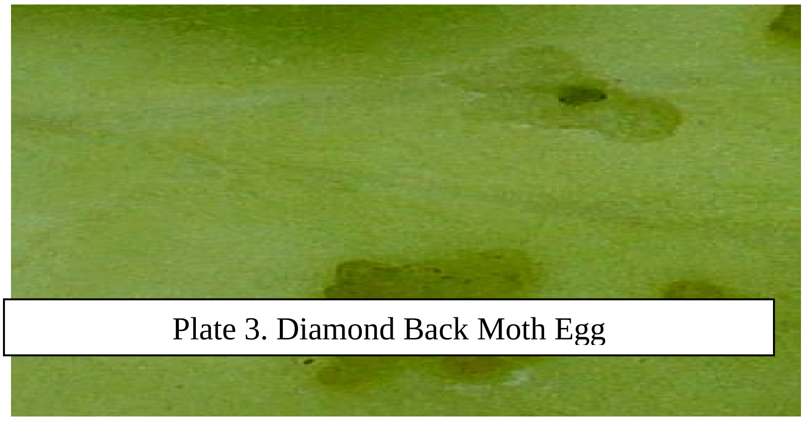

Plate 3. Diamond Back Moth Egg

Plate 4. Diamond Back Moth Larvae

Plate 6. Diamond Back Moth Adult

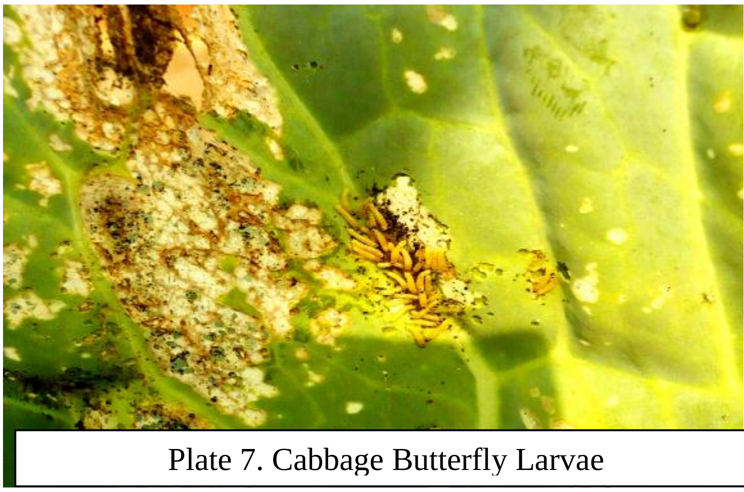

Plate 7. Cabbage Butterfly Larvae

Plate 9. Tobacco Caterpillar Larvae

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted to evaluate the effectiveness of *Trichogramma evanescens* for ecofriendly management of Lepidopterous insect pests of cabbage in the field under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2011 to March, 2012. The findings of the study have been interpreted and discussed under the following sub-headings:

4.1 Percent (%) leaf infestation by number at different days after transplanting

The significant variations were observed among the different treatments used for the management practices in terms of percent leaf infestation by number due to attack of cabbage caterpillar at different days after transplanting (DAT).

At of 53 DAT, the highest leaf infestation by number (40.90 %) was recorded in T_9 (untreated control) which was statistically different from all other treatments followed by T_5 (29.30%) comprised of Tricho Paper Card @ 0.20 g/plot at 10 days interval and T_6 (26.60%) comprised of Tricho Paper Card @ 0.30 g/plot at 10 days interval (Table 1). On the other hand, the lowest leaf infestation (13.40%) was observed in T_4 comprised of Tricho Paper Card @ 0.50 g/plot at 5 days interval which was statistically similar with T_3 (15.60%) comprised of Tricho Paper Card @ 0.40 g/plot at 5 days interval followed by T_1 (Tricho Paper Card @ 0.20 g/plot at 5 days interval), T_2 (Tricho Paper Card @ 0.30 g/plot at 5 days interval), T_7 (Tricho Paper Card @ 0.40 g/plot at 10 days interval) and T_8 (Tricho Paper Card @ 0.50 g/plot at 10 days interval).

At 60 DAT, the highest leaf infestation (74.00%) was recorded in T_9 comprised of untreated control, followed by T_5 (62.80%) and T_6 (61.00%) (Table 1). On the other hand, the lowest leaf infestation was recorded in T_4 (45.80%) which was significantly different from all other treatments. More or less similar trends were also recorded at 67, 74, 81 and 88 DAT in terms of percent leaf infestation by number (Table 1).

The highest leaf infestation by number was found in T_9 (untreated control) at 67, 74, 81 and 88 DAT (55.60%, 45.70%, 52.21% and 71.50%, respectively). Among the treated plots, the highest leaf infestation by number was found in T_5 (Tricho Paper Card @ 0.20 g/plot at 10 days interval) at 67, 74, 81 and 88 DAT (43.20%, 39.90, 40.42% and 37.20%, respectively where the lowest was found in T_4 (Tricho Paper Card @ 0.50 g/plot at 5 days interval) at 67, 74, 81 and 88 DAT (31.30%, 27.30%, 29.105 and 19.30%, respectively).

In terms of mean infestation of leaf by number, the highest was found in T_9 (56.60%) comprised of untreated control which was significantly different from all other treatments followed by T_1 (39.70%), T_5 (42.10%) and T_6 (40.90%). On the other hand the lowest mean leaf infestation by number was found in T_4 (27.70%) which was closely followed by T_3 (31.90%) and significantly different from all other treatments (Table 1). In case of percent reduction over control, the highest reduction over control was achieved by T_4 (51.00%) where the lowest was found in T_5 (25.60%) (Table 1).

From the Table 1 it was observed that among the different treatments, T_4 performed best in reducing the leaf infestation of cabbage (51.00%) by number due to attack of cabbage caterpillar than the other treatments; whereas, T_5 showed the least performance results in reducing the leaf infestation of cabbage (25.60%) by number over control. As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of percent leaf infestation of cabbage by number was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$. Similar findings were also found by other researchers, but not directly with Cabbage. Bigler (1994) also reported the same trend of results to control lepidopteran pest (European corn borer) by using *Trichogramma*.

Table 1: Effect of different management practices on the leaf infestation of cabbage by number due to attack of cabbage caterpillar at different days after transplanting (DAT)

Treatment	Percent (%) Leaf infestation							
	53 DAT	60 DAT	67 DAT	74 DAT	81 DAT	88 DAT	Mean infestation	% reduction over control
T_1	22.90 bc	58.90 bc	39.90 b	40.50 ab	38.70 bc	37.40 bc	39.70 bc	**29.80**
T_2	21.50 bc	55.00 bc	38.00 b	32.80 ab	35.90 bd	32.20 bc	35.90 ce	**36.50**
T_3	15.60 c	51.30 bc	32.60 b	33.60 ab	30.70 d	28.68 c	31.90 ef	**43.60**
T_4	13.40 c	45.80 c	31.30 b	27.30 b	29.10 d	19.30 d	27.70 f	**51.00**
T_5	29.30 b	62.80 ab	43.20 ab	39.90 ab	40.42 b	37.20 bc	42.10 b	**25.60**
T_6	26.60 b	61.00 ab	41.50 b	35.70 ab	38.90 bc	38.20 b	40.90 bc	**27.70**
T_7	22.90 bc	56.10 bc	39.30 b	35.80 ab	36.00 bd	34.20 bc	37.40 cd	**33.90**
T_8	19.50 bc	52.80 bc	36.20 b	31.60 b	31.90 cd	30.20 bc	33.70 de	**40.00**
T_9	40.90 a	74.00 a	55.60 a	45.70 a	52.20 a	71.50 a	56.60 a	-
LSD(0.01)	19.846	14.41	12.91	13.69	7.865	8.831	4.657	-
CV (%)	24.02	14.49	18.74	22.03	12.24	13.96	7.00	-

In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance.
Values are the means of three replications.
T_1 = Tricho Paper Card @ 0.20 g/plot at 5 days interval;
T_2 = Tricho Paper Card @ 0.30 g/plot at 5 days interval;
T_3 = Tricho Paper Card @ 0.40 g/plot at 5 days interval;
T_4 = Tricho Paper Card @ 0.50 g/plot at 5 days interval;
T_5 = Tricho Paper Card @ 0.20 g/plot at 10 days interval;
T_6 = Tricho Paper Card @ 0.30 g/plot at 10 days interval;
T_7 = Tricho Paper Card @ 0.40 g/plot at 10 days interval;
T_8 = Tricho Paper Card @ 0.50 g/plot at 10 days interval;
T_9 = Untreated control.

4.2 Number of holes/leaf of a plant

The significant variations were observed among different treatments used for the management practices in terms of number of holes/leaf of a plant due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 2). At 53 DAT, the highest number of holes/leaf of a plant (5.70) was recorded in T_9 which was significantly different from all other treatments followed by T_5 (5.00) and T_6 (5.00) and T_1 (5.00) (Table 1). On the other hand, the lowest number of holes/leaf of a plant (4.40) was observed in T_4 which was statistically similar with T_3 (4.60) followed by T_2 (4.70).

At 60 DAT, the highest number of holes/leaf of a plant (5.80) was recorded in T_9, followed by T_5 (5.00) and T_6 (4.90) (Table 1). On the other hand, the lowest number of holes/leaf of a plant (4.00) was recorded in T_4 which was significantly different from all other treatments. More or less similar trends were also recorded in case of 67, 74, 81 and 88 DAT in terms of percent leaf infestation and the number of holes/leaf of a plant (Table 2).

At 67, 74, 81 and 88 DAT, the highest number of holes/leaf of a plant was found in T_9 (5.90, 6.20, 6.30 and 6.90 at 67, 74, 81 and 88 DAT, respectively) but among the treated plots, the highest number of holes/leaf of a plant (4.50, 4.30, 3.70 and 3.60 at 67, 74, 81 and 88 DAT, respectively) was found in T_5 where the lowest number of holes/leaf of a plant (3.60, 3.10, 2.40 and 2.30 at 67, 74, 81 and 88 DAT, respectively) was observed in T_4.

Among the treated plots, T_4 showed the best performance and next to T_3, T_2 and at all management stages of cabbage caterpillar (Table 2). T_5 showed the lowest performance as management practices against cabbage caterpillar followed by T_6, T_1 and T_7.

In terms of mean infestation/leaf of a plant, the highest infestation was found in T_9 (6.10) comprised of untreated control which was significantly different from all other treatments. Among the management practices, the highest infestation was found in T_5 (4.40) followed by T_6 (4.20), T_1 (4.10) and T_7 (4.00). On the other hand, the lowest mean infestation was observed in T_4 (3.30) which was followed by T_3 (3.60) (Table 2).

In case of percent reduction over control, the highest reduction over control was achieved by T_4 (45.9%) where the lowest was found in T_5 (27.80%) which was very close to T_6 (32.70%) and T_1 (32.70) (Table 2).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best in reducing the infestation intensity of leaf of cabbage by number of holes (45.9%) due to attack of cabbage caterpillar than the other treatments; whereas, T_5 showed the least performance in reducing the infestation intensity of leaf of cabbage by number of holes (27.80%) over control. As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of percent infestation intensity of leaf of cabbage by number of holes was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$. Similar type of findings was also found by other researchers, but not directly with Cabbage. Kring and Smith (1995) also reported the same trend of results to control lepidopteran pests (Cotton bollworm and budworm) by using *Trichogramma*.

Table 2: Effect of different management practices on the infestation intensity of leaf of cabbage by number of holes due to attack of cabbage caterpillar at different days after transplanting (DAT)

Treatment	Number of holes /leaf of a plant							
	53 DAT	60 DAT	67 DAT	74 DAT	81 DAT	88 DAT	Mean infestation	% reduction Over control
T_1	5.00 b	4.90 bc	4.40 b	3.60 cd	3.60 bc	3.30 b	4.10 cd	**32.70**
T_2	4.70 bcd	4.40 cd	4.20 b	3.50 de	3.20 bcd	3.00 bc	3.80 ef	**37.70**
T_3	4.60 cd	4.50 cd	4.10 bc	3.20 ef	2.90 de	2.70 bc	3.60 g	**40.90**
T_4	4.40 d	4.00 d	3.60 c	3.10 f	2.40 e	2.30 c	3.30 g	**45.90**
T_5	5.00 b	5.00 b	4.50 b	4.30 b	3.70 b	3.60 b	4.40 b	**27.80**
T_6	5.00 b	4.90 bc	4.40 b	3.80 c	3.60 bc	3.50 b	4.20 bc	**31.10**
T_7	4.80 bcd	4.60 bc	4.30 b	3.60 cd	3.50 bc	3.20 bc	4.00 de	**34.40**
T_8	4.80 bcd	4.40 cd	4.20 b	3.40 def	3.10 cd	2.80 bc	3.80 fg	**37.70**
T_9	5.70 a	5.80 a	5.90 a	6.20 a	6.30 a	6.90 a	6.10 a	**-**
LSD(0.01)	0.44	0.52	0.62	0.33	0.59	1.04	0.17	**-**
CV (%)	5.24	6.39	8.10	4.95	9.51	17.18	2.35	**-**

In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance. Values are the means of three replications.
T_1 = Tricho Paper Card @ 0.20 g/plot at 5 days interval;
T_2 = Tricho Paper Card @ 0.30 g/plot at 5 days interval;

T_3 = Tricho Paper Card @ 0.40 g/plot at 5 days interval;
T_4 = Tricho Paper Card @ 0.50 g/plot at 5 days interval;
T_5 = Tricho Paper Card @ 0.20 g/plot at 10 days interval;
T_6 = Tricho Paper Card @ 0.30 g/plot at 10 days interval;
T_7 = Tricho Paper Card @ 0.40 g/plot at 10 days interval;
T_8 = Tricho Paper Card @ 0.50 g/plot at 10 days interval;
T_9 = Untreated control.

4.3 Incidence of larva

Significant variations were observed among the different treatments used for the management practices in terms of Incidence of larva due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 3). At 53 DAT the highest incidence of larva (9.00) was recorded in T_9 which was significantly different from all other treatments. But in the treated plots, the highest incidence of larva was found in T_5 (6.90) which was closely followed by T_6 (6.2) and T_7 (6.2). On the other hand, the lowest incidence of larva was observed in T_4 (4.0) which was closely followed by T_8 (4.90).

At 60 DAT, the highest incidence of larva (9.60) was recorded in T_9 where the lowest incidence of larva (3.90) was found from T_4 comprised of. But in treated plot, T_5 showed the highest incidence of larva (5.80) followed by T_6 (5.30) at 60 DAT. More or less similar trend of the incidence of Incidence of larva were recorded at 67, 74, 81 and 90 DAT. But the rate of incidence of larva incidence was decreasing with the increase of the age of the cabbage plants within the treated plots. But opposite feature was found in untreated control treatment (T_9).

Among the treated plots, T_4 showed the best performance and next to T_3, T_2 and T_8 at all management stages of cabbage caterpillar (Table 2). Again, T_5 showed the highest incidence of larva (6.90, 5.80, 5.60, 5.40, 5.20 and 5.0 at 53, 60, 67, 74, 81 and 88 DAT, respectively) followed by T_6, T_1 and T_7.

In terms of mean number of larva, the highest mean incidence was found in T_9 (12.38) comprised of untreated control which was significantly different from all other treatments. Among the management practices, the highest incidence was found in T_5 (5.6) which was significantly similar with T_6 (5.2) followed by T_1 (4.9) and T_7 (4.6). On the other hand, the lowest mean incidence of larva was observed in T_4 (3.50) which was significantly similar with T_3 (4.10) and T_8 (4.00) (Table 3).

In case of % reduction over control, the highest reduction over control was achieved by T_4 (71.70%) where the lowest was found in T_5 (54.70%) which was very close to T_6 (57.90%) (Table 3).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best in reducing the incidence of cabbage caterpillar (71.70%) throughout the cropping season than the other treatments; whereas, T_5 showed the least performance in reducing the incidence of cabbage caterpillar (54.70%) over control. As a result, the order of trend of efficacy among the different treatments including one untreated control in terms of reducing the incidence of cabbage caterpillar throughout the cropping season was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$. About similar findings were also found by several researchers, but not directly with Cabbage. Bigler (1994) also reported the same trend of results to control lepidopteran pest (European corn borer) by using *Trichogramma*.

Table 3: Effect of different management practices on the incidence of cabbage caterpillar at different days after transplanting (DAT)

Treatment	**Incidence of larva/plant**							
	53 DAT	**60 DAT**	**67 DAT**	**74 DAT**	**81 DAT**	**88 DAT**	**Mean infestatio**	**% reduction**

							n	over control
T_1	6.10 bd	5.00 bc	4.80 bd	4.70 bc	4.50 cd	4.20 cd	4.90 bd	**60.40**
T_2	5.90 bd	4.40 bc	4.30 bd	4.20 cd	4.00 d	3.70 df	4.40 cd	**64.40**
T_3	5.50 cd	4.00 bc	3.90 cd	4.10 cd	4.00 d	3.20 fg	4.10 de	**66.80**
T_4	4.00 e	3.90 c	3.50 d	3.30 d	3.20 e	2.90 g	3.50 e	**71.70**
T_5	6.90 b	5.80 b	5.60 b	5.40 b	5.20 b	5.00 b	5.60 b	**54.70**
T_6	6.20 bc	5.30 bc	5.20 bc	5.10 bc	4.90 bc	4.60 bc	5.20 bc	**57.90**
T_7	6.20 bc	4.60 bc	4.40 bd	4.40 bd	4.20 d	3.90 ce	4.60 cd	**62.80**
T_8	4.90 de	4.20 bc	4.10 cd	4.00 cd	3.80 de	3.40 eg	4.00 de	**67.60**
T_9	9.00 a	9.60 a	11.0 a	13.67 a	14.53 a	17.4 a	12.38 a	**-**
LSD(0.01)	1.25	1.80	1.43	1.23	0.70	0.71	0.91	**-**
CV (%)	11.84	19.96	15.85	13.36	7.53	7.72	9.73	**-**

In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance.
Values are the means of three replications.
T_1 = Tricho Paper Card @ 0.20 g/plot at 5 days interval;
T_2 = Tricho Paper Card @ 0.30 g/plot at 5 days interval;
T_3 = Tricho Paper Card @ 0.40 g/plot at 5 days interval;
T_4 = Tricho Paper Card @ 0.50 g/plot at 5 days interval;
T_5 = Tricho Paper Card @ 0.20 g/plot at 10 days interval;
T_6 = Tricho Paper Card @ 0.30 g/plot at 10 days interval;
T_7 = Tricho Paper Card @ 0.40 g/plot at 10 days interval;
T_8 = Tricho Paper Card @ 0.50 g/plot at 10 days interval;
T_9 = Untreated control.

4.4 Percent (%) leaf area damage by Number of larva

Significant variations were observed among the different treatments used for the management practices in terms of % leaf area damage due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 4). At 53 DAT the highest % leaf area damage (4.20) was recorded in control treatment (T_9) which was significantly different from all other treatments. But among the treated plots, the highest % leaf area damage was found in T_5 (3.30) which was statistically identical with T_6 (3.20). On the other hand, the lowest % leaf area damage was observed in T_4 (1.50) which was significantly similar with T_3 (2.10). The results obtained from other treatments of T_7, T_2, T_1 and T_8 respectively showed gradually decreased % leaf area damage. More or less similar trend of the incidence of % leaf area damage were recorded at 60, 67, 74, 81 and 90 DAT. But the rate of % leaf area damage incidence was decreasing with the increase of the age of the cabbage plants within the treated plots. But opposite feature was found in (T_9).

In case of mean incidence, more or less similar trend of % leaf area damage occurrence was also observed and the highest occurrence (4.80) was recorded in (T_9) which was significantly different from all other treatments. But in case of treated plots, T_5 (2.10) showed the highest % leaf area damage which was statistically identical with T_6 (2.10) followed by T_1 (1.8) and T_8 (1.8). On the other hand, the lowest % leaf area damage occurrence (1.20) was held in T_4 which was closely followed by T_3 (1.50).

In case of % reduction over control, the highest reduction over control was achieved by T_4 (75%) where the lowest was found in T_5 (56.20%) which was very close to T_6 (56.20%) (Table 4).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best results in reducing the leaf area damage (75%) by cabbage caterpillar throughout the cropping season than the other treatments; whereas, T_5 showed the least performance results in reducing the leaf area damage (56.20%) by cabbage caterpillar throughout the cropping season over control. As a result, the order of trend of efficacy among the different treatments including one untreated control in terms of reducing the leaf area damage by cabbage caterpillar throughout the cropping season was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$. About similar type of findings were also found by other researchers, but not directly with Cabbage. Saour (2004) also reported the same trend of results to control lepidopteran pest (spruce budworm) by using *Trichogramma*.

Table 4: Effect of different management practices on the leaf area damage by cabbage caterpillar at different days after transplanting (DAT)

Treatment	Leaf area damage (%)							
	53 DAT	60 DAT	67 DAT	74 DAT	81 DAT	88 DAT	Mean infestation	% reduction over

								control
T_1	2.60 bc	2.00 cd	2.00 cd	1.60 c	1.50 cd	1.10 bc	1.80 bcd	**62.50**
T_2	2.70 bc	2.00 cd	1.90 ce	1.60 c	1.40 cd	0.80 bd	1.70 cd	**64.50**
T_3	2.10 cd	1.90 d	1.50 ef	1.40 cd	1.30 cd	0.60 cd	1.50 de	**68.70**
T_4	1.50 d	1.40 e	1.30 f	1.30 d	1.30 d	0.40 d	1.20 e	**75.00**
T_5	3.30 ab	2.60 b	2.60 b	1.90 b	1.60 c	0.70 bd	2.10 b	**56.20**
T_6	3.20 ab	2.40 bc	2.30 bc	1.60 c	2.10 b	1.00 bd	2.10 b	**56.20**
T_7	2.80 bc	2.00 cd	1.90 ce	1.60 c	1.50 cd	1.30 b	1.80 bc	**62.50**
T_8	2.60 bc	1.80 d	1.60 def	1.50 cd	1.30 cd	0.70 bd	1.60 cd	**67.00**
T_9	4.20 a	4.20 a	4.40 a	4.60 a	5.20 a	6.00 a	4.80 a	**-**
LSD(0.01)	0.99	0.45	0.49	0.21	0.37	0.62	0.34	**-**
CV (%)	20.42	11.55	13.04	6.41	10.81	24.86	9.43	**-**

In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance. Values are the means of three replications.
T_1 = Tricho Paper Card @ 0.20 g/plot at 5 days interval;
T_2 = Tricho Paper Card @ 0.30 g/plot at 5 days interval;
T_3 = Tricho Paper Card @ 0.40 g/plot at 5 days interval;
T_4 = Tricho Paper Card @ 0.50 g/plot at 5 days interval;
T_5 = Tricho Paper Card @ 0.20 g/plot at 10 days interval;
T_6 = Tricho Paper Card @ 0.30 g/plot at 10 days interval;
T_7 = Tricho Paper Card @ 0.40 g/plot at 10 days interval;
T_8 = Tricho Paper Card @ 0.50 g/plot at 10 days interval;
T_9 = Untreated control.

4.5 Percent (%) head infestation by number at vegetative stage

Significant variations were observed among the different treatments used for the management practices in terms of % head infestation by number due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 5). At 53 DAT the highest % head infestation by number (46.60%) was recorded in T_9. But among the treated plots, the highest % head infestation by number was found in T_5 (46.60%) which was statistically identical with T_6 (46.60) and T_9 and closely followed by T_1 (40.00%). On the other hand, the lowest % head infestation by number was observed in T_4 (23.30%) which was significantly similar with T_3 (30.00%) and T_8 (30.00%) (Table 5).

More or less similar trend of % head infestation by number were recorded at 60, 67, 74, 81 and 90 DAT. But the rate of % head infestation by number incidence was decreasing with the increase of the age of the cabbage plants within the treated plots. But opposite feature was found in T_9 i.e. gradually increased % head infestation by number was found with the increase of the age of the cabbage.

In case of mean infestation, more or less similar trend of % head infestation by number occurrence was also observed and the highest % head infestation (57.70%) was recorded in T_9 which was significantly different from all other treatments. But in case of treated plots, T_5 (33.30%) showed the highest % head infestation by number which was statistically similar with T_6 (28.80%) followed by T_1 (24.40%). On the other hand, the lowest % head infestation by number (10.50%) was held in T_4 which was closely followed by T_3 (15.50%).

In case of % reduction over control, the highest reduction over control was achieved by T_4 (81.1%) where the lowest was found in T_5 (42.28%) which was very close to T_6 (50%) (Table 5).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best results in reducing the infestation of cabbage head (81.1%) by number due to attack of cabbage caterpillar at Vegetative Stage than the other treatments; whereas, T_5 showed the least performance results in reducing the infestation of cabbage head (42.28%) by number due to attack of cabbage caterpillar at Vegetative Stage over control. As a result, the order of trend of efficacy among the different treatments including one untreated control in terms of reducing the infestation of cabbage head by number due to attack of cabbage caterpillar at Vegetative Stage was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$. About similar type of findings were also found by other researchers, but not directly with Cabbage. Kring and Smith (1995) also reported the same trend of results to control lepidopteran pests (Cotton bollworm and budworm) by using *Trichogramma*.

Table 5: Effect of different management practices on the infestation of cabbage head by number due to attack of cabbage caterpillar at Vegetative Stage

Treatment	**% Head infestation by number**							
	53	**60**	**67**	**74**	**81 DAT**	**88**	**Mean**	**%**

	DAT	DAT	DAT	DAT		DAT	infestation	reduction over control
T_1	40.00 ab	33.30 bc	23.30 c	20.00 bc	20.00 c	10.00 bc	24.40 cd	**57.70**
T_2	33.30 bc	30.00 bd	20.00 c	20.00 bc	13.33 d	10.00 bc	21.10 de	**63.40**
T_3	30.00 bc	20.00 de	16.60 cd	10.00 cd	10.00 de	6.60 bc	15.50 ef	**73.10**
T_4	23.30 c	16.60 e	6.60 d	6.60 d	6.60 e	3.30 c	10.50 f	**81.10**
T_5	46.60 a	40.00 b	36.67 b	30.00 b	30.00 b	16.60 b	33.30 b	**42.28**
T_6	46.60 a	40.00 b	26.67 bc	26.60 b	20.00 c	13.30 bc	28.80 bc	**50.00**
T_7	33.30 bc	30.00 bd	23.30 c	20.00 bc	10.00 de	10.00 bc	21.10 de	**63.40**
T_8	30.00 bc	26.60 ce	16.60 cd	13.30 cd	13.30 d	6.60 bc	17.70 de	**69.30**
T_9	46.60 a	53.30 a	56.60 a	63.30 a	63.30 a	63.30 a	57.70 a	**-**
LSD(0.01)	13.22	12.80	13.32	10.40	6.342	10.40	6.865	**-**
CV (%)	20.83	22.84	30.57	25.75	17.67	38.63	15.48	**-**

In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance.
Values are the means of three replications.
T_1 = Tricho Paper Card @ 0.20 g/plot at 5 days interval;
T_2 = Tricho Paper Card @ 0.30 g/plot at 5 days interval;
T_3 = Tricho Paper Card @ 0.40 g/plot at 5 days interval;
T_4 = Tricho Paper Card @ 0.50 g/plot at 5 days interval;
T_5 = Tricho Paper Card @ 0.20 g/plot at 10 days interval;
T_6 = Tricho Paper Card @ 0.30 g/plot at 10 days interval;
T_7 = Tricho Paper Card @ 0.40 g/plot at 10 days interval;
T_8 = Tricho Paper Card @ 0.50 g/plot at 10 days interval;
T_9 = Untreated control.

4.6 Leaf infestation intensity at harvesting

Significant variations were observed among the different treatments used for the management practices in terms of leaf infestation intensity due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 6). The highest leaf infestation intensity (26.45%) was recorded in T_9 which was significantly different from all other treatments. But in the treated plots, the highest leaf infestation intensity was found in T_5 (18.50%) which was statistically similar with T_6 (17.50%) followed by T_1 (15.04%). On the other hand, the lowest leaf infestation intensity was observed in T_4 (7.40%) which was significantly similar with T_3 (10.40%) followed by T_2 (12.30%) and T_8 (10.70%). The results obtained from other treatments showed intermediate level of leaf infestation intensity. So, it can be observed that the leaf infestation intensity among the treatments from highest to the lowest was shown as $T_9 > T_5 > T_6 > T_1 > T_7 > T_2 > T_8 > T_3 > T_4$.

In case of % reduction over control, the highest reduction over control on leaf infestation intensity was achieved by T_4 (72.0%) where the lowest was found in T_5 (30.00%) which was very close to T_6 (33.80%) (Table 6).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best in reducing the infestation intensity of leaf (72.0%) of cabbage by cabbage caterpillar at harvesting than the other treatments; whereas, T_5 showed the least performance in reducing the infestation intensity of leaf (30.00%) of cabbage by cabbage caterpillar at harvesting over control. As a result, the order of trend of efficacy among the different treatments including one untreated control in terms of reducing the infestation intensity of leaf of cabbage by cabbage caterpillar at harvesting was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$. About similar type of findings were also found by other researchers, but not directly with Cabbage. Segers *et. al*, (1984) also reported the same trend of results to control lepidopteran pests (Cotton bollworm and budworm) by using *Trichogramma*.

Table 6: Effect of different management practices on the infestation intensity of leaf of cabbage by cabbage caterpillar at harvesting

Treatment	leaf infestation intensity	% reduction over control
T_1	15.04 bd	**43.10**
T_2	12.30 df	**53.40**
T_3	10.40 fg	**60.60**
T_4	7.40 g	**72.00**
T_5	18.50 b	**30.00**
T_6	17.50 bc	**33.80**
T_7	14.20 ce	**46.30**
T_8	10.70 eg	**59.50**
T_9	26.45 a	**-**
LSD(0.01)	3.55	**-**
CV (%)	13.92	**-**

In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance. Values are the means of three replications.

T_1 = Tricho Paper Card @ 0.20 g/plot at 5 days interval;
T_2 = Tricho Paper Card @ 0.30 g/plot at 5 days interval;
T_3 = Tricho Paper Card @ 0.40 g/plot at 5 days interval;
T_4 = Tricho Paper Card @ 0.50 g/plot at 5 days interval;
T_5 = Tricho Paper Card @ 0.20 g/plot at 10 days interval;
T_6 = Tricho Paper Card @ 0.30 g/plot at 10 days interval;
T_7 = Tricho Paper Card @ 0.40 g/plot at 10 days interval;
T_8 = Tricho Paper Card @ 0.50 g/plot at 10 days interval;
T_9 = Untreated control.

4.7 Infestation intensity of head of cabbage by number of holes during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of number of holes/infested head due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 7). The highest number of holes/infested head (30.33) was recorded inT_9 which was significantly different from all other treatments. But among the treated plots, the highest number of holes/infested head was found in T_5 (24.67) which was statistically similar with T_6 (24.33) followed by T_1 (23.00) and T_7 (23.00). On the other hand, the lowest number of holes/infested head was observed in T_4 (13.00) which was significantly different from all other treatments followed by T_3 (16.00) and T_7 (19.67). The result obtained from other treatments showed intermediate level of number of holes/infested head. So, it can be observed that the number of holes/infested head among the treatments from highest to the lowest was shown as $T_9 > T_5 > T_6 > T_1 > T_7 > T_2 > T_8 > T_3 > T_4$.

In case of % reduction over control, the highest on number of holes/infested head was achieved by T_4 (57.10%) where the lowest was found in T_5 (18.60%) which was very close to T_6 (19.70%) (Table 7).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best in reducing the infestation intensity of head (57.10%) of cabbage by number of holes due to attack of cabbage caterpillar at harvesting than the other treatments; whereas, T_5 showed the least performance in reducing the infestation intensity of head (18.60%) of cabbage by number of holes due to attack of cabbage caterpillar at harvesting over control. As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of reducing the infestation intensity of head of cabbage by number of holes due to attack of cabbage caterpillar at harvesting was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$. About similar findings were also found by other researchers, but not directly with Cabbage. Afroz, (2011) reported the same trend of results to control lepidopteran pest (okra shoot and fruit borer) of okra by using *Trichogramma*. In that experiment, the third highest reduction of number of bores per fruit was recorded in case of *Trichogramma evanescence* egg parasitoid @ 0.5g/plot at 7 days interval treatment and that was 62.09 %.

Table 7: Effect of different management practices on the infestation intensity of head of cabbage by number of holes due to attack of cabbage caterpillar at harvesting

Treatment	Number of holes / infested head	% reduction over control
T_1	23.00 c	**24.10**
T_2	20.67 d	**31.80**
T_3	16.00 e	**47.20**
T_4	13.00 f	**57.10**
T_5	24.67 b	**18.60**
T_6	24.33 b	**19.70**
T_7	23.00 c	**24.10**
T_8	19.67 d	**35.10**
T_9	30.33 a	**-**
LSD(0.01)	1.25	**-**
CV (%)	3.34	**-**

In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance.
Values are the means of three replications.
T_1 = Tricho Paper Card @ 0.20 g/plot at 5 days interval;
T_2 = Tricho Paper Card @ 0.30 g/plot at 5 days interval;
T_3 = Tricho Paper Card @ 0.40 g/plot at 5 days interval;
T_4 = Tricho Paper Card @ 0.50 g/plot at 5 days interval;
T_5 = Tricho Paper Card @ 0.20 g/plot at 10 days interval;
T_6 = Tricho Paper Card @ 0.30 g/plot at 10 days interval;
T_7 = Tricho Paper Card @ 0.40 g/plot at 10 days interval;
T_8 = Tricho Paper Card @ 0.50 g/plot at 10 days interval;
T_9 = Untreated control.

4.8 Incidence of cabbage caterpillar in the infested head at harvesting

Significant variations were observed among the different treatments used for the management practices in terms of number of larva/infested head due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 8).

The highest number of larva/infested head (9.30) was recorded in T_9 which was significantly different from all other treatments. But among the treated plots, the highest number of larva/infested head was found in T_5 (5.60) which was statistically similar with T_6 (4.60) followed by T_1 (4.30). On the other hand, the lowest number of larva/infested head was observed in T_4 (1.30) which was significantly similar with T_3 (2.00) followed by T_8 (3.00). The results obtained from other treatments gave intermediate level of number of larva/infested head. So, it can be observed that the number of larva/infested head among the treatments from highest to the lowest was as $T_9 > T_5 > T_6 > T_1 > T_7 > T_2 > T_8 > T_3 > T_4$.

In case of % reduction over control, the highest reduction over control on number of larva/infested head was achieved by T_4 (86%) where the lowest was found in T_5 (39.70%) which was very close to T_6 (50.50%) (Table 8).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best in reducing the incidence of cabbage caterpillar (86%) in the infested head at harvesting than the other treatments; whereas, T_5 showed the least performance in reducing the incidence of cabbage caterpillar (39.70%) in the infested head at harvesting over control. As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of reducing the incidence of cabbage caterpillar (39.70%) in the infested head at harvesting was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$. About similar findings were also found by other researchers, but not directly with Cabbage. Afroz, (2011) reported the same trend of results to control lepidopteran pest (okra shoot and fruit borer) of okra by using *Trichogramma*. In that experiment, the third highest reduction of number of larvae per fruit was recorded in case of *Trichogramma evanescence* egg parasitoid @ 0.5g/plot at 7 days interval treatment and that was 60.0 %.

Table 8: Effect of different management practices on the incidence of cabbage caterpillar in the infested head at harvesting

Treatment	Number of larva / infested head	% reduction over control
T_1	4.30 cd	**53.70**
T_2	3.30 de	**64.50**
T_3	2.00 fg	**78.40**
T_4	1.30 g	**86.00**
T_5	5.60 b	**39.70**
T_6	4.60 bc	**50.50**
T_7	3.60 ce	**61.20**
T_8	3.00 ef	**67.70**
T_9	9.30 a	**-**
LSD(0.01)	1.23	**-**
CV (%)	17.20	**-**

In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance.
Values are the means of three replications.
T_1 = Tricho Paper Card @ 0.20 g/plot at 5 days interval;
T_2 = Tricho Paper Card @ 0.30 g/plot at 5 days interval;
T_3 = Tricho Paper Card @ 0.40 g/plot at 5 days interval;
T_4 = Tricho Paper Card @ 0.50 g/plot at 5 days interval;
T_5 = Tricho Paper Card @ 0.20 g/plot at 10 days interval;
T_6 = Tricho Paper Card @ 0.30 g/plot at 10 days interval;
T_7 = Tricho Paper Card @ 0.40 g/plot at 10 days interval;
T_8 = Tricho Paper Card @ 0.50 g/plot at 10 days interval;
T_9 = Untreated control.

4.9 Percent (%) infestation of head by number during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of number of % infestation of head by number due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 9). The highest % infestation of head by number (60) was recorded in T_9 which was significantly different from all other treatments. But in the treated plots, the highest % infestation of head by number was found in

T_5 (16.6) which was closely followed by T_1 (13.30%), T_2 (13.30%), T_6 (13.30%) and T_7 (13.30). On the other hand, the lowest % infestation of head by number was observed in T_4 (3.30) which was significantly similar with T_3 (6.60) followed by T_8 (10).

The results obtained from other treatments gave intermediate level of % infestation of head by number. So, it can be observed that the % infestation of head by number among the treatments from highest to the lowest was shown as $T_9 > T_5 > T_6 > T_1 > T_7 > T_2 > T_8 > T_3 > T_4$.

In case of percent reduction over control, the highest reduction over control on percent infestation of head by number was achieved by T_4 (94.50%) where the lowest was found in T_5 (72.30%) which was very close to T_6 (77.80%) (Table 9).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best results in reducing the infestation intensity of head by number by cabbage caterpillar (94.50%) at harvesting than the other treatments; whereas, T_5 showed the least performance results in reducing the infestation intensity of head by number by cabbage caterpillar (72.30%) at harvesting over control. As a result, the order of trend of efficacy among the different treatments including one untreated control in terms of reducing the infestation intensity of head by number by cabbage caterpillar at harvesting was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$. About similar findings were also found by several researchers, but not directly with Cabbage. Afroz (2011) reported the same trend of results to control lepidopteran pest (okra shoot and fruit borer) of okra by using *Trichogramma*. In that experiment, the third highest reduction of fruit infestation by number was recorded in case of *Trichogramma evanescence* egg parasitoid @ 0.5g/plot at 7 days interval treatment and that was 72.22 %. Rahman (2011) also found similar type of results in case of controlling lepidopteran pest, tomato fruit borer.

Table 9: Effect of different management practices on the infestation intensity of head by cabbage caterpillar at harvesting

Treatment	% infestation of head by number	% reduction over control
T_1	13.30 bc	**77.80**
T_2	13.30 bc	**77.80**
T_3	6.60 cd	**89.00**
T_4	3.30 d	**94.50**
T_5	16.60 b	**72.30**
T_6	13.30 bc	**77.80**
T_7	13.30 bc	**77.80**
T_8	10.00 bd	**83.30**
T_9	60.00 a	**-**
LSD(0.01)	9.12	**-**
CV (%)	31.62	**-**

In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance.
Values are the means of three replications.
T_1 = Tricho Paper Card @ 0.20 g/plot at 5 days interval;
T_2 = Tricho Paper Card @ 0.30 g/plot at 5 days interval;
T_3 = Tricho Paper Card @ 0.40 g/plot at 5 days interval;
T_4 = Tricho Paper Card @ 0.50 g/plot at 5 days interval;
T_5 = Tricho Paper Card @ 0.20 g/plot at 10 days interval;
T_6 = Tricho Paper Card @ 0.30 g/plot at 10 days interval;
T_7 = Tricho Paper Card @ 0.40 g/plot at 10 days interval;
T_8 = Tricho Paper Card @ 0.50 g/plot at 10 days interval;
T_9 = Untreated control.

4.10 Percent (%) infestation of head by weight during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of number of % infestation of head by weight due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 10). The highest % infestation of head by weight (47.83%) was recorded in T_9 which was significantly different from all other treatments. But in the treated plots, the highest % infestation of head by weight was found in T_5 (10.70%) which was statistically identical with T_6 (8.70%) and closely followed by T_1 (7.20%), T_2 (7.62%), T_7 (7.30%) and T_8 (6.80%). On the other hand, the lowest % infestation of head by weight was observed in T_4 (1.70%) which was significantly similar with T_3 (3.70%). So, it can be observed that the % infestation of head by weight among the treatments from highest to the lowest was shown as $T_9 > T_5 > T_6 > T_2 > T_7 > T_1 > T_8 > T_3 > T_4$.

In case of % reduction over control, the highest reduction over control on % infestation of head by weight was achieved by T_4 (93.90%) where the lowest was found in T_6 (81.80%) (Table 10).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best results in reducing the infestation intensity of head by weight (93.90%) by cabbage caterpillar at harvesting than the other treatments; whereas, showed the least performance results in reducing the infestation intensity of head by weight (81.80%) by cabbage caterpillar at harvesting over control. As a result, the order of trend of efficacy among the different treatments including one untreated control in terms of reducing the infestation intensity of head by weight by cabbage caterpillar at harvesting was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$. About similar findings were also found by several researchers, but not directly with Cabbage. Afroz (2011) reported the same trend of results to control lepidopteran pest (okra shoot and fruit borer) of okra by using *Trichogramma*. In that experiment, the third highest reduction of fruit infestation by weight was recorded in case of *Trichogramma evanescence* egg parasitoid @ 0.5g/plot at 7 days interval treatment and that was 66.11 %. Rahman (2011) also reported similar type of results in case of controlling lepidopteran pest, tomato fruit borer.

Table 10: Effect of different management practices on the infestation intensity of head by weight by cabbage caterpillar at harvesting

Treatment	% head infestation by weight	% reduction over control
T_1	7.20 bc	**84.90**
T_2	7.60 bc	**84.00**
T_3	3.70 cd	**92.20**
T_4	1.70 d	**93.90**
T_5	10.70 b	**84.90**
T_6	8.70 b	**81.80**
T_7	7.30 bc	**84.70**
T_8	6.80 bc	**85.70**
T_9	47.83 a	**-**
LSD(0.01)	3.92	**-**
CV (%)	20.04	**-**

In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance. Values are the means of three replications.
T_1 = Tricho Paper Card @ 0.20 g/plot at 5 days interval;
T_2 = Tricho Paper Card @ 0.30 g/plot at 5 days interval;
T_3 = Tricho Paper Card @ 0.40 g/plot at 5 days interval;
T_4 = Tricho Paper Card @ 0.50 g/plot at 5 days interval;
T_5 = Tricho Paper Card @ 0.20 g/plot at 10 days interval;
T_6 = Tricho Paper Card @ 0.30 g/plot at 10 days interval;
T_7 = Tricho Paper Card @ 0.40 g/plot at 10 days interval;
T_8 = Tricho Paper Card @ 0.50 g/plot at 10 days interval;
T_9 = Untreated control.

4.11.1 Height of head during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of height of head due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 11). The highest height of head (21.60 cm) was recorded in T_4 which was statistically identical with T_3 (20.00 cm). On the other hand, the lowest head height (12.90 cm) was found in T_9 which was significantly different from all other treatments. But in the treated plots, the lowest head height (15.17 cm) was found in T_5 which was closely followed by T_1 (16.10 cm), T_2 (16.50 cm), T_6 (15.80 cm), T_7 (16.40 cm) and T_8 (17.10 cm). The gradually decreased trend was observed in case of height of head as $T_4 > T_3 > T_8 > T_7 > T_2 > T_1 > T_6 > T_5 > T_9$.

In terms of % increase over control, the highest increase over control on head height was observed with the treatment of T_4 (67.40%) which was very close to T_3 (55%) where the lowest was achieved from T_5 (17%) which was very close to T_6 (22.40%) (Table 11).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best results in percent increasing height of head (67.40%) at harvesting than the other treatments; whereas, T_6 showed the least performance results in percent increasing height of head (17%) at harvesting over control. As a result, the order of trend of efficacy among the different treatments including one untreated control in terms of in percent increasing height of head at harvesting was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$. About similar findings were also found by several researchers, but not directly with Cabbage. Afroz (2011) reported the same trend of results to control lepidopteran pest (okra shoot and fruit borer) of okra by using *Trichogramma*. In that experiment, the third highest length of fruit was recorded in case of *Trichogramma evanescence* egg parasitoid @ 0.5g/plot at 7 days interval treatment.

4.11.2 Diameter of head during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of diameter of head due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 11). The highest diameter of head (24.03 cm) was recorded in T_4 which was statistically similar with T_3 (23.00 cm) followed by T_2 (22.10 cm) and T_8 (22.47 cm). On the other hand, the lowest head diameter (15.30 cm) was found in T_9 which was significantly different from all other treatments. But in the treated plots, the lowest head diameter (20.47 cm) was found in T_5 which was statistically identical with T_6 (20.87 cm) and closely followed by T_1 (21.37 cm) and T_7 (21.83 cm). The gradually decreased trend was observed in case of diameter of head as $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$.

In terms of % increase over control, the highest increase over control on head diameter was observed with the treatment of T_4 (57%) where the lowest was achieved from T_5 (33.70%) which was very close to T_6 (35.90%) (Table 11).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best results in percent increasing diameter of head (57%) at harvesting than the other treatments; whereas, T_6 showed the least performance results in percent increasing diameter of head (33.70%) at harvesting over control. As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of in percent increasing diameter of head at harvesting was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$. About similar findings were also found by several researchers, but not directly with Cabbage. Afroz (2011) reported the same trend of results to control lepidopteran pest (okra shoot and fruit borer) of okra by using *Trichogramma*. In that experiment, the third highest girth of fruit was recorded in case of *Trichogramma evanescence* egg parasitoid @ 0.5g/plot at 7 days interval treatment.

Table 11. Effect of different management practices on yield contributing characters of Cabbage

Treatment	Height of head	% increase over control	Diameter of head	% increase over control
T_1	16.10 b	24.80	21.37 bc	**39.60**
T_2	16.50 b	27.90	22.10 abc	**44.40**
T_3	20.00 a	55.00	23.00 ab	**50.30**
T_4	21.60 a	67.40	24.03 a	**57.00**
T_5	15.17 b	17.00	20.47 c	**33.70**
T_6	15.80 b	22.40	20.87 c	**35.90**
T_7	16.40 b	27.10	21.83 bc	**42.90**

T_8	17.10 b	34.70	22.47 abc	**46.40**
T_9	12.90 c	-	15.3 d	**-**
LSD(0.01)	1.96	-	2.03	**-**
CV (%)	6.74	-	5.54	**-**

In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance. Values are the means of three replications.
T_1 = Tricho Paper Card @ 0.20 g/plot at 5 days interval;
T_2 = Tricho Paper Card @ 0.30 g/plot at 5 days interval;
T_3 = Tricho Paper Card @ 0.40 g/plot at 5 days interval;
T_4 = Tricho Paper Card @ 0.50 g/plot at 5 days interval;
T_5 = Tricho Paper Card @ 0.20 g/plot at 10 days interval;
T_6 = Tricho Paper Card @ 0.30 g/plot at 10 days interval;
T_7 = Tricho Paper Card @ 0.40 g/plot at 10 days interval;
T_8 = Tricho Paper Card @ 0.50 g/plot at 10 days interval;
T_9 = Untreated control.

4.12.1 Single head weight (kg) during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of single head weight due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 12). The highest single head weight (2.80 kg) was recorded in T_4 which was statistically similar with T_3 (2.60 kg) followed by T_8 (2.40 kg). On the other hand, the lowest single head weight (1.37 kg) was found in T_9 which was significantly different from all other treatments. But in the treated plots, the lowest single head weight (1.90 kg) was found in T_5 which was closely followed by T_6 (2 kg) and T_1 (2.10 kg).

The results obtained from T_2 (2.20 kg) and T_7 (2.20 kg) gave intermediate results of single head weight. The gradually decreased rank was observed in case of single head weight as $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$ (Table 12).

4.12.2 Healthy head weight (kg) during harvesting

Significant variations were observed among the different treatments used for the management practices in terms of healthy head weight/plot due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 12). The highest healthy head weight/plot (27.60 kg) was recorded in T_4 which was statistically similar with T_3 (25.60 kg) followed by T_8 (23.10 kg). On the other hand, the lowest healthy head weight/plot (7.10 kg) was found in T_9 which was significantly different from all other treatments. But in the treated plots, the lowest healthy head weight/plot (16.90 kg) was found in T_5 which was closely followed by T_6 (19 kg).

The results obtained from T_1 (20.10 kg), T_2 (20.70 kg) and T_7 (20.80 kg) gave intermediate results of healthy head weight/plot. The gradually decreased trend was observed in case of healthy head weight/plot as $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$ (Table 12).

4.12.3 Total yield (t/ha)

Significant variations were observed among the different treatments used for the management practices in terms of total yield (t/ha) due to attack of cabbage caterpillar at different days after transplanting (DAT) (Table 12). The highest total yield (93.70 t/ha) was recorded in T_4 which was statistically similar with T_3 (88.60 t/ha) followed by T_8 (82.80 t/ha), the lowest total yield (45.70 t/ha) was found in T_9 which was significantly different from all other treatments. But in the treated plots, the lowest total yield (63.30 t/ha) was found in T_5 which was closely followed by T_6 (69.30 t/ha) and T_1 (72.20 t/ha).

The results obtained from T_2 (74.60 t/ha) and T_7 (74.70 t/ha) gave intermediate results of total yield. The gradually decreased trend was observed in case of total yield as $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$ (Table 12).

In terms of % increase over control, the highest increase over control on total yield was observed where the lowest was achieved from T_5 (38.50%) followed by T_6 (51.60%) (Table 12).

From the above mentioned findings it was revealed that among the different treatments, T_4 performed best in percent increase of total yield of cabbage (105%) at harvesting than the other treatments; whereas, T_6 showed the least performance in percent increase of total yield of cabbage (38.50%) at harvesting over control. As a result, the order of rank of efficacy among the different treatments including one untreated control in terms of percent increase of total yield of cabbage at harvesting was $T_4 > T_3 > T_8 > T_2 > T_7 > T_1 > T_6 > T_5 > T_9$. About similar findings were also found by several researchers, but not directly with Cabbage. Afroz

(2011) reported the same trend of results to control lepidopteran pest (okra shoot and fruit borer) of okra by using *Trichogramma*. In that experiment, the third highest increase of total yield of okra was recorded in case of *Trichogramma evanescence* egg parasitoid @ 0.5g/plot at 7 days interval treatment and that was 59.17 %.

Table 12: Effect of different management practices on the yield of cabbage

Treatment	Single head weight (kg)	Healthy head weight (kg/ plot)	Yield (t/ha)	
			Total yield (t/ha)	% increase of total yield over control
T_1	2.10 de	20.10 d	72.20 de	**57.90**
T_2	2.20 cd	20.70 cd	74.60 cd	**63.20**
T_3	2.60 ab	25.60 ab	88.60 ab	**93.80**
T_4	2.80 a	27.60 a	93.70 a	**105.00**
T_5	1.90 e	16.90 e	63.30 e	**38.50**
T_6	2.00 de	19.00 de	69.30 de	**51.60**
T_7	2.20 cd	20.80 cd	74.70 cd	**63.40**
T_8	2.40 bc	23.10 bc	82.80 bc	**81.10**
T_9	1.37 f	7.10 f	45.70 f	**-**
LSD(0.01)	0.28	2.8	9.6	**-**
CV (%)	7.56	8.04	7.56	**-**

In column, means containing same letter indicate significantly similar under DMRT at 1% level of significance. Values are the means of three replications.
T_1 = Tricho Paper Card @ 0.20 g/plot at 5 days interval;
T_2 = Tricho Paper Card @ 0.30 g/plot at 5 days interval;
T_3 = Tricho Paper Card @ 0.40 g/plot at 5 days interval;
T_4 = Tricho Paper Card @ 0.50 g/plot at 5 days interval;
T_5 = Tricho Paper Card @ 0.20 g/plot at 10 days interval;
T_6 = Tricho Paper Card @ 0.30 g/plot at 10 days interval;
T_7 = Tricho Paper Card @ 0.40 g/plot at 10 days interval;
T_8 = Tricho Paper Card @ 0.50 g/plot at 10 days interval;
T_9 = Untreated control.

4.13 Relationship between leaf infestation intensity and head weight

The results revealed that there was strong negative correlation between leaf infestation intensity and single head weight, which suggested that with the increase of leaf infestation intensity there was a partially influenced on single head weight. A linear regression was fitted between single head weight and leaf infestation intensity (Fig.1). The correlation coefficient (r) was – 0.98 and the contribution of the regression (R^2) were 0.9609. In the present study, it was observed that lepidopteros insect infestation on leaf passively prevented plants to produce and supply nutrient and water. The plants became stunted with a reduced single head weight.

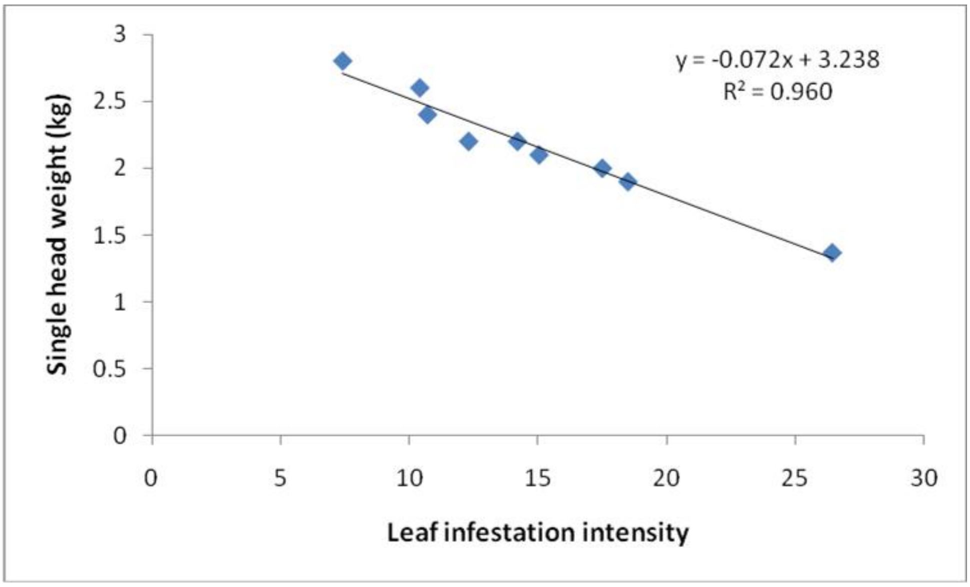

Figure 1: Relationship between leaf infestation intensity and single head weight obtained from different treatments

4.14 Relationship between leaf infestation intensity and yield (t/ha)

The results revealed that there was strong negative correlation between leaf infestation intensity and total yield/ha, which suggested that with the increase of leaf infestation intensity there was a significant influence on total yield/ha. A linear regression was fitted between total yield/ha weight and leaf infestation intensity (Fig.2). The correlation coefficient (r) was – 0.982 and the contribution of the regression (R^2) were 0.9651. In the present study, it was observed that lepidopteros insect infestation on leaf passively prevented plants to produce and supply nutrient and water. The plants became stunted with a reduced yield.

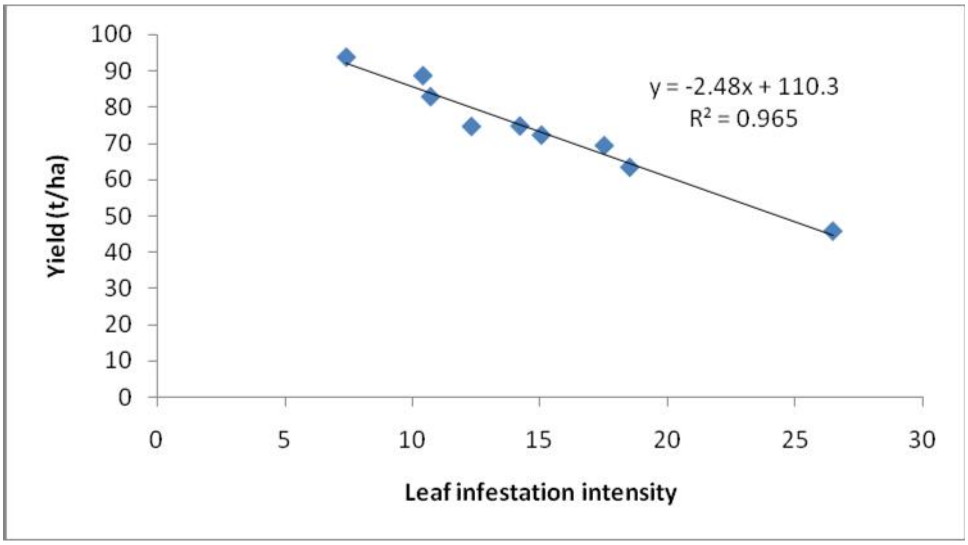

Figure 2: Relationship between leaf infestation intensity and total yield (t/ha) obtained from different treatments

4.15 Relationship between number of larvae and leaf infestation intensity

The results revealed that there was strong positive correlation between number of larvae and leaf infestation intensity, which suggested that with the increase of number of larvae there was a significant influenced on leaf infestation intensity. A linear regression was fitted between leaf infestation intensity and number of larvae (Fig.3). The correlation coefficient (r) was 0.987 and the contribution of the regression (R^2) was 0.9741. In the present study, it was observed that number of larvae of lepidopterous insect on cabbage leaf passively prevented plants to produce and supply nutrient and water and number of larvae create more leaf infestation. The plants became stunted with a increased leaf infestation intensity.

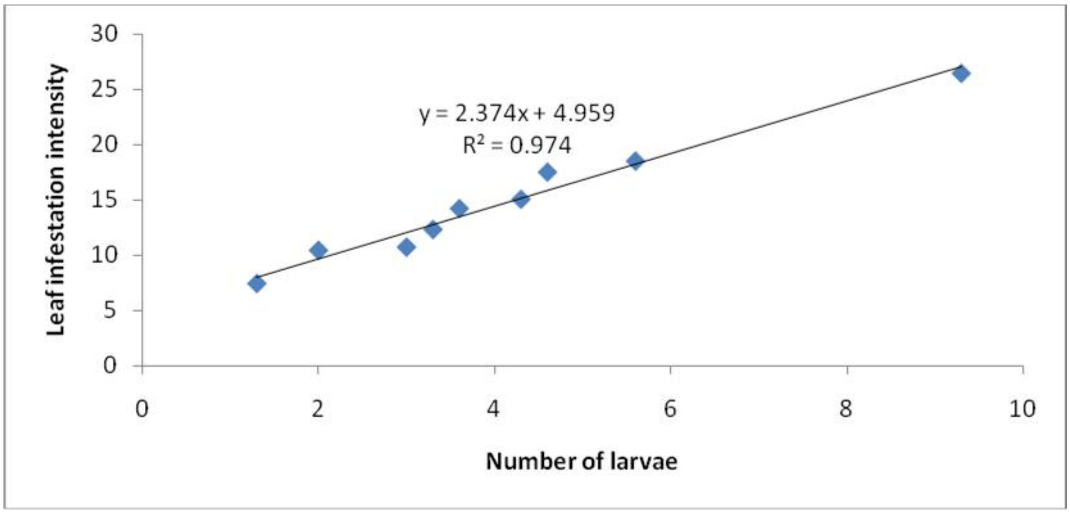

Figure 3: Relationship between number of larvae and leaf infestation intensity obtained from different treatments.

4.16 Relationship between number of larvae and leaf area damage

The results revealed that there was strong positive correlation between number of larvae and leaf area damage, which suggested that with the increase of number of larvae, there was a significant influenced on leaf area damage. A linear regression was fitted between leaf area damage and number of larvae (Fig.4). The correlation coefficient (r) was 0.942 and the contribution of the regression (R^2) was 0.8884. In the present study, it was observed that number of larvae of lepidopterous insect on cabbage leaf area damage passively prevented plants to produce and supply nutrient and water and more number of larvae causes more leaf area damage. The plants became stunted with increased leaf area damage.

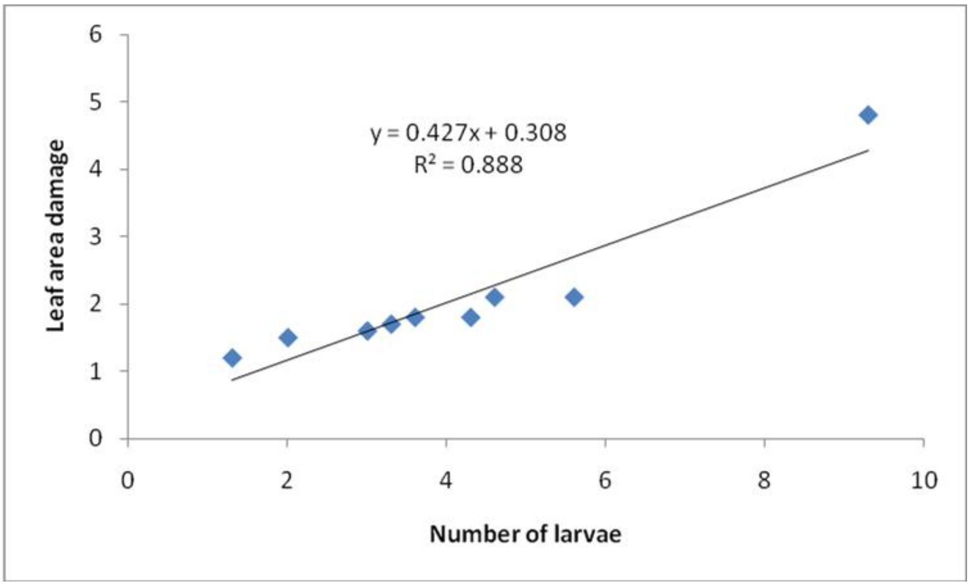

Figure 4: Relationship between number of larvae and leaf area damage obtained from different treatments

4.17 Relationship between number of larvae/infested head and numbers of holes/infested head

The results revealed that there was strong positive correlation between number of larvae/infested head and numbers of holes/infested head, which suggested that with the increase of number of larvae/infested head there was a significant influenced on leaf area damage and caused increased numbers of holes/infested head. A linear regression was fitted between numbers of larvae/infested head and numbers of holes/infested head (Fig.5). The correlation coefficient (r) was 0.9403 and the contribution of the regression (R^2) was 0.8842. In the present study, it was observed that number of larvae of lepidopterous insect on cabbage passively prevented plants to produce and supply nutrient and water and more numbers of holes/infested head was observed with the presence of more number of larvae/infested head. The plants became stunted with increased numbers of holes/infested head.

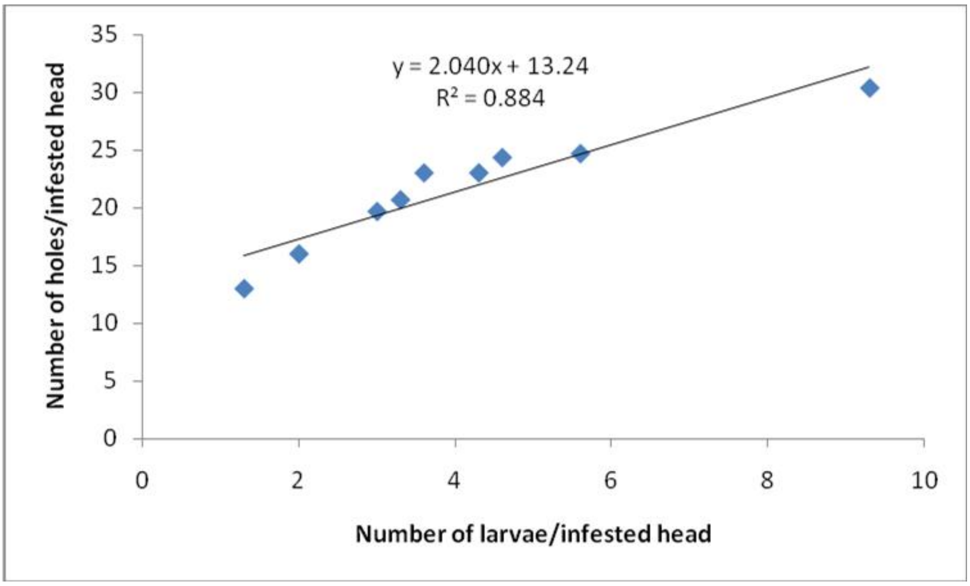

Figure 5: Relationship between number of larvae/infested head and numbers of holes/infested head obtained from different treatments

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the Entomology farm, Sher-e-Bangla Agricultural University during the period from October 2011 to March 2012 to evaluate the effectiveness of *Trichogramma evanescens* for hazards free management of lepidopterous insect pests of cabbage in the field.

Nine treatments viz. (i) T_1 (Tricho Paper Card @ 0.20 gm/plot at 5 days interval), (ii) T_2 (Tricho Paper Card @ 0.30 gm/plot at 5 days interval), (ii) T_3 (Tricho Paper Card @ 0.40 gm/plot at 5 days interval), (iv) T_4 (Tricho Paper Card @ 0.50 gm/plot at 5 days interval), (v) T_5 (Tricho Paper Card @ 0.20 gm/plot at 10 days interval), (vi) T_6 (Tricho Paper Card @ 0.30 gm/plot at10 days interval), (vii) T_7 (Tricho Paper Card @ 0.40 gm/plot at 10 days interval), (viii) T_8 (Tricho Paper Card @ 0.50 gm/plot at10 days interval) and (ix) T_9 (Untreated Control) were included in this study. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replication.

Results showed that the significant variations were observed among different ages of the cabbage plant in terms of % leaf infestation, number of holes /leaf of a plant, number of larva, leaf area damage (%) and % head infestation by number. From beginning of yield formation stage to at harvest, significant results was also observed in terms of leaf infestation intensity, number of holes / infested head, number of larva/infested head, % infestation of head by number, % head infestation by weight, height of head, diameter of head, single head weight (kg), healthy head weight (kg/ plot) and total yield (t/ha).

Results showed that the lowest % leaf infestation (13.4, 45.80, 31.30, 27.30, 29.10 and 19.30 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. mean=27.70) was observed in T_4 where the highest (40.90, 74.00, 55.60, 45.70, 52.20 and 71.50 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. mean=56.60) was obtained from T_9. But in the treated plots, the highest % leaf infestation (29.30, 62.80, 43.20, 39.90, 40.42 and 37.20 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. mean=42.10) was achieved from T_5.

Again, it was found that the lowest number of holes /leaf of a plant (4.40, 4.00, 3.60, 3.10, 2.40 and 2.30 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. mean=3.30) was observed in T_4 where the highest (5.70, 5.80, 5.90, 6.20, 6.30 and 6.90 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. mean=6.10) was obtained from T_9. But in the treated plots, the highest number of holes /leaf of a plant (5.00, 5.00, 4.50, 4.30, 3.70 and 3.6 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. mean=4.40) was achieved from T_5.

Results also showed that the lowest number of larva (4.00, 3.90, 3.50, 3.30, 3.20 and 2.90 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. mean=3.50) was observed in T_4 where the highest (9.00, 9.60, 11.00, 13.67, 14.53 and 17.40 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. mean=12.38) was obtained from T_9. But in the treated plots, the highest number of larva (6.90, 5.80, 5.60, 5.40, 5.20 and 5.60 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. i.e. mean=4.40) was achieved from T_5.

It is also found that the lowest % leaf area damage (1.50, 1.40, 1.30, 1.30, 1.30 and 0.40 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. mean=1.20) was observed in T_4 where the highest (4.20, 4.20, 4.40, 4.60, 5.20 and 6.00 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. mean=4.80) was obtained from T_9. But in the treated plots, the highest % leaf area damage (3.30, 2.60, 2.60, 1.90, 1.60 and 0.70 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. mean=2.10) was achieved from T_5.

Results showed that the lowest % head infestation by number (23.30, 16.60, 6.60, 6.60 and 3.30 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. mean=10.50) was observed in T_4 where the highest (46.60, 53.30, 56.60, 63.30, 63.30 and 63.30 at 53, 60, 67, 74, 81% and 88

DAT, respectively i.e. mean=57.70%) was obtained from T_9. But in the treated plots, the highest % head infestation by number (46.60, 40.00, 36.67, 30.00, 30.00 and 16.60 at 53, 60, 67, 74, 81 and 88 DAT, respectively i.e. mean=33.30) was achieved from T_5.

Again, the lowest leaf infestation intensity (7.40%), number of holes/infested head (13.00), number of larva/infested head (1.30), % infestation of head by number (3.30), % head infestation by weight (1.70), highest height of head (21.60 cm), diameter of head (24.03 cm), single head weight (2.80 kg), healthy head weight (27.60 kg/plot) and highest total yield (93.70 t/ha) were observed in T_4 where the highest leaf infestation intensity (26.45%), number of holes / infested head (30.33), number of larva / infested head (9.30), % infestation of head by number (60.00), % head infestation by weight (47.83), lowest height of head (12.90 cm), diameter of head (15.30 cm), single head weight (1.37 kg), healthy head weight (7.10 kg/plot) and lowest total yield (47.70 t/ha) were obtained from T_9. But in the treated plots, the highest leaf infestation intensity (18.50%), number of holes / infested head (24.67), number of larva / infested head (5.60), % infestation of head by number (16.60), % head infestation by weight (10.70), lowest height of head (15.17 cm), diameter of head (20.47 cm), single head weight (1.90 kg), healthy head weight (16.90 kg/plot) and lowest total yield (63.30 t/ha) were obtained from T_5.

In terms of % reduction or increase over control the highest % reduction of leaf infestation over control (51.00%), % reduction of number of holes /leaf of a plant over control (45.9%), % reduction of number of larva over control (71.7%), % reduction of leaf area damage (%) over control (75%), % reduction of head infestation by number over control (81.1%), % reduction of leaf infestation over control (72.0%), % reduction of number of holes/infested head over control (57.1%),% reduction of number of larva/infested head over control (86.0%),% reduction of infestation of head by number (94.5%), % reduction of head infestation by weight over control (93.9%), % increase of height of head over control (67.4%), % increase of diameter of head over control (57.0%) and % increase of Total yield over control (105.0%) were achieved by T_4 where the lowest % reduction of leaf infestation over control (25.60%), % reduction of number of holes /leaf of a plant over control (27.8%), % reduction of number of larva over control (54.7%), % reduction of leaf area damage (%) over control (56.2%), % reduction of head infestation by number over control (42.28%), % reduction of leaf infestation over control (30.0%), % reduction of number of holes / infested head over control (18.6%), % reduction of number of larva / infested head over control (39.7%), % reduction of infestation of head by number (72.3%), % reduction of head infestation by weight over control (84.9%), % increase of height of head over control (17.0%), % increase of diameter of head over control (33.7%) and % increase of total yield over control (38.5%) were achieved by T_5.

From the above discussion on summary, it can be concluded that, the treatment of T_4 comprised of Tricho Paper Card @ 0.50 g/plot at 5 days interval gave the highest performance compared to all other treatments used under the present study where the lowest performance was obtained by control treatment. On the other hand, the lowest performance among the treated plots was achieved by T_5 (Tricho Paper Card @ 0.20 g/plot at 10 days interval).

Considering the findings of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in more control condition with highly equipped laboratory condition;
2. Further trials may be done at different locations of the country.

CHAPTER VI

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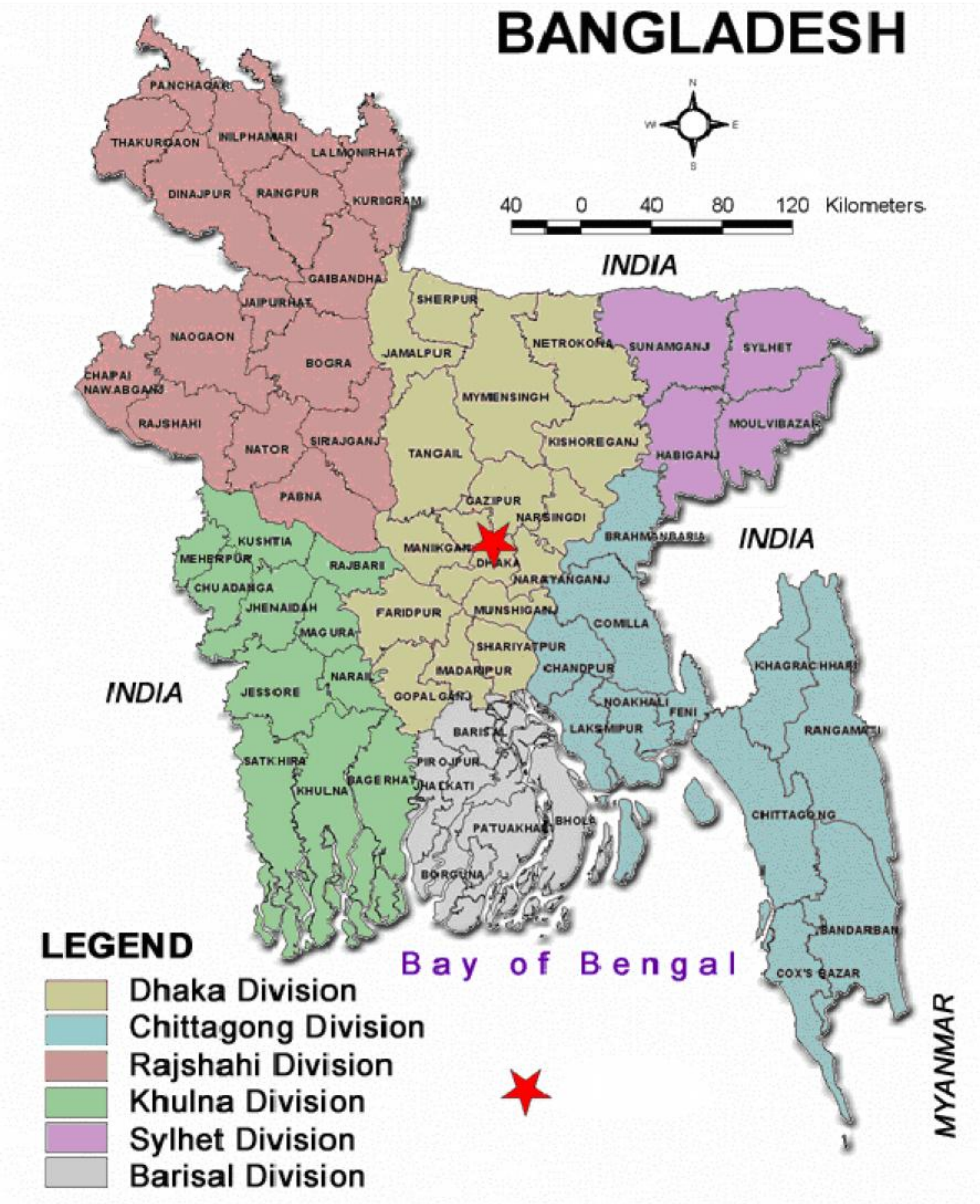
APPENDICES

Appendix I. Experimental site at Sher-e-Bangla Agricultural University, Dhaka-1207.



Experimental site

Figure: The map of Bangladesh showing experimental site

Appendix II. Physical characteristics and chemical composition of soil of the experimental plot.

Soil Characteristics	**Analytical results**
Agrological Zone	Madhupur Tract
P^H	5.47 – 5.63
Organic matter	0.82
Total N (%)	0.43
Available phosphorous	22 ppm
Exchangeable K	0.42 meq / 100 g soil

Appendix III. Monthly average air temperature, relative humidity, rainfall and sunshine hours during the experimental period (October, 2011 to March, 2012) at Sher - e - Bangla Agricultural University campus.

Month	Year	Monthly average air temperature (^0C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
Oct	2011	31.00	23.30	27.10	75.30	208	212.16
Nov.	2011	27.28	11.15	19.26	68.34	Trace	220.80
Dec.	2011	27.19	10.91	19.05	70.05	Trace	212.50
Jan.	2012	25.23	18.20	21.80	74.90	4.0	195.00
Feb.	2012	31.35	19.40	25.33	68.78	3.0	225.50
Mar.	2012	33.20	22.00	27.60	64.13	Trace	220.30

Source: Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka – 1212.

Appendix IV. Effect of different management practices on the leaf infestation of cabbage by number due to attack of cabbage caterpillar.

Source of variance	Degrees of Freedom	Mean square of % leaf infestation						
		53 DAT	60 DAT	67 DAT	74 DAT	81 DAT	88 DAT	Mean infestation
Replication	2	0.38	1.44	1.52	0.70	1.39	2.02	1.95
Factor A	8	9.04*	9.25*	15.94*	90.26*	14.16**	12.57**	12.74**
Error	16	2.36	3.32	5.60	62.584	20.64	2.03	1.23

Appendix V. Effect of different management practices on the infestation intensity of leaf of cabbage by number of holes due to attack of cabbage caterpillar.

Source of variance	Degrees of Freedom	Mean square of number of holes/leaf of a plant						
		53 DAT	60 DAT	67 DAT	74 DAT	81 DAT	88 DAT	Mean infestation
Replication	2	0.28	0.06	0.08	0.30	0.77	0.08	0.01
Factor A	8	0.41*	0.79**	1.26**	2.65**	3.65**	5.43**	1.95**
Error	16	0.07	0.09	0.13	0.04	0.12	0.37	0.01

Appendix VI. Effect of different management practices on the incidence of cabbage caterpillar throughout the cropping season.

Source of variance	Degrees of Freedom	Mean square of number of larva						
		53 DAT	60 DAT	67 DAT	74 DAT	81 DAT	88 DAT	Mean infestation
Replication	2	0.37	0.81	0.06	0.38	0.78	0.06	0.15
Factor A	8	5.61**	9.43**	5.23**	8.79**	6.23**	6.12**	8.47**
Error	16	0.52	1.09	0.90	0.51	0.16	0.17	0.28

Appendix VII. Effect of different management practices on the leaf area damage by cabbage caterpillar throughout the cropping season

Source of variance	Degrees of Freedom	Mean square of leaf area damage (%)						
		53 DAT	60 DAT	67 DAT	74 DAT	81 DAT	88 DAT	Mean infestation
Replication	2	0.06	0.08	0.06	0.08	0.03	0.02	0.11
Factor A	8	1.70*	1.93**	2.49**	3.19**	4.62**	9.27**	3.29**
Error	16	0.33	0.07	0.08	0.02	0.05	0.12	0.04

Appendix VIII. Effect of different management practices on the infestation of cabbage head by number due to attack of cabbage caterpillar at Vegetative Stage

Source of variance	Degrees of Freedom	Mean square of % head infestation by number						
		53 DAT	60 DAT	67 DAT	74 DAT	81 DAT	88 DAT	Mean infestation
Replication	2	1.33	3.000	2.59	1.44	1.12	1.18	1.73
Factor A	8	12.00*	13.00*	10.59**	8.67*	9.81*	10.33*	7.97*
Error	16	2.33	3.17	3.25	3.11	1.426	2.11	1.73

Appendix IX. Effect of different management practices on leaf infestation intensity, number of holes / infested head, number of larva / infested head, % head infestation by number and % head infestation by weight of cabbage by cabbage caterpillar at harvesting

Source of variance	Degrees of Freedom	Mean square				
		Leaf infestation intensity	Number of holes / infested head	Number of larva / infested head	% head infestation by number	% head infestation by weight
Replication	2	1.74	0.48	0.26	1.11	0.23
Factor A	8	9.94**	7.62**	6.59**	8.67**	5.98**
Error	16	1.21	0.52	0.51	2.78	1.14

Appendix X. Effect of different management practices on yield and yield contributing characters of Cabbage

Source of variance	Degrees of Freedom	Mean square				
		Height of head	Diameter of head	Single head weight (kg)	Healthy head weight (kg/ plot)	Total yield (t/ha)
Replication	2	0.64	3.20	0.08	1.19	2.48
Factor A	8	9.85**	18.62**	0.55**	10.41**	18.15**
Error	16	1.29	1.38	0.08	2.62	3.25